National Park Service
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Natural Resource Stewardship and Science

Sand Creek Massacre National Historic Site

Natural Resource Condition Assessment

Natural Resource Report NPS/SOPN/NRR—2013/734



ON THE COVER

Cottonwood stand on misty day at Sand Creek Massacre NHS. Photo: Paul Feldman, Postmodern Company

Sand Creek Massacre National Historic Site

Natural Resource Condition Assessment

Natural Resource Report NPS/SOPN/NRR—2013/734

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Executive Summary

The Natural Resource Condition Assessment (NRCA) Program, administered by National Park Service's (NPS) Water Resources Division, aims to provide documentation about current conditions of important park natural resources through a spatially explicit, multi-disciplinary synthesis of existing scientific data and knowledge. The NRCA for Sand Creek Massacre National Historic Site began in 2012, and 14 focal study natural resources were chosen for the Historic Site's NRCA. These resources were organized into three categories that ranged in contexts from broader to narrower including landscape-scale, supporting environment (i.e., physical resources), and biological integrity, which included wildlife and vegetation topics.

Sand Creek Massacre was provided protection on November 7, 2000 ([Public Law 106-465]) and dedicated as a national park unit in 2007. The Historic Site was set aside to preserve a significant event in United States history that occurred on November 29, 1864 when a peaceful village of Cheyenne and Arapaho Indians, under the leadership of Chief Black Kettle, were attacked by United States and volunteer Colorado soldiers. The surrounding area still maintains its rural and remote area much like it did in 1864, which has helped to preserve and protect the Historic Site's natural and cultural resources.

The landscape scale resources chosen for this assessment included viewshed, night sky, and soundscape. Overall, these resources are in relatively good condition. The condition of these three resources alone afford visitors an opportunity to experience the solitude and connection to Sand Creek Massacre's "sense of place," commemorating the fallen victims during the 1864 attack.

The Historic Site's supporting physical environment resource topics included air quality, geology, groundwater, and surface water. Interestingly, many of these topics, with the exception of air quality, are lacking specific data to provide insight into current condition and trend at the Historic Site.

The resource topics related to vegetation include grasslands, riparian habitat, and exotic plants. All of these are in very good condition, including exotic plants, which is rare. In fact, in over 57% of park-wide plots surveyed for exotics, none were found, meaning the grasslands and riparian habitats are in good condition, especially relative to the presence of exotic plants.

Finally, the wildlife resource topics included landbirds, prairie dogs, rare vertebrates, and aquatic invertebrates. Condition for landbirds is good, however, in early 2010 the sylvatic plague decimated the prairie dog colonies in and adjacent to the Historic Site. Data gaps exist for the remaining wildlife topics.

Acknowledgements

We wish to thank Jeff Albright, program lead of the Natural Resource Condition Assessment Program, Water Resources Program Center, National Park Service, who provided programmatic insight and guidance on project development and review. The authors are grateful to the staff at the National Park Service Natural Resource Stewardship and Science Directorate for their technical expertise, guidance, and reviews of their respective subjects. We are extremely grateful to all subject matter experts who provided valuable information pertaining to their respective areas of research and expertise. Their input helped to create a relevant, scientifically based document that provided new insights into the communities and processes found and occurring throughout the Historic Site. Finally, we would like to express our gratitude and thanks to Sand Creek Massacre and Bent's Old Fort NHS staffs, whose input and reviews were very appreciated. To all those remaining who reviewed and commented on this report, thank you. Your contributions have increased its professional value.



ROBERT BENNETTS

Chapter 1: NRCA Background Information

Natural Resource Condition Assessments (NRCAs) evaluate current conditions for a subset of natural resources and resource indicators in national park units, hereafter "parks." NRCAs also report on trends in resource condition (when possible), identify critical data gaps, and characterize a general level of confidence for study findings. The resources and indicators emphasized in a given project depend on the park's resource setting, status of resource stewardship planning and science in identifying high-priority indicators, and availability of data and expertise to assess current conditions for a variety of potential study resources and indicators.

NRCAs represent a relatively new approach to assessing and reporting on park resource conditions. They are meant to complement — not replace — traditional issue- and threat-based resource assessments. As distinguishing characteristics, all NRCAs:

- are multi-disciplinary in scope;[1]
- employ hierarchical indicator frameworks;[2]
- identify or develop reference conditions/values for comparison against current conditions;[3]
- emphasize spatial evaluation of conditions and GIS (map) products;[4]
- summarize key findings by park areas; and[5]
- follow national NRCA guidelines and standards for study design and reporting products.

NRCAs Strive to Provide…

- Credible condition reporting for a subset of important park natural resources and indicators
- Useful condition summaries by broader resource categories or topics, and by park areas

1. The breadth of natural resources and number/type of indicators evaluated will vary by park.
2. Frameworks help guide a multi-disciplinary selection of indicators and subsequent "roll up" and reporting of data for measures] conditions for indicators] condition summaries by broader topics and park areas
3. NRCAs must consider ecologically-based reference conditions, must also consider applicable legal and regulatory standards, and can consider other management-specified condition objectives or targets; each study indicator can be evaluated against one or more types of logical reference conditions. Reference values can be expressed in qualitative to quantitative terms, as a single value or range of values; they represent desirable resource conditions or, alternatively, condition states that we wish to avoid or that require a follow-on response (e.g., ecological thresholds or management "triggers").
4. As possible and appropriate, NRCAs describe condition gradients or differences across a park for important natural resources and study indicators through a set of GIS coverages and map products.
5. In addition to reporting on indicator-level conditions, investigators are asked to take a bigger picture (more holistic) view and summarize overall findings and provide suggestions to managers on an area-by-area basis: 1) by park ecosystem/habitat types or watersheds, and 2) for other park areas as requested.

Important NRCA Success Factors

- Obtaining good input from park staff and other NPS subject-matter experts at critical points in the project timeline
- Using study frameworks that accommodate meaningful condition reporting at multiple levels (measures / indicators) broader resource topics, and park areas
- Building credibility by clearly documenting the data and methods used, critical data gaps, and level of confidence for indicator-level condition findings

Although the primary objective of NRCAs is to report on current conditions relative to logical forms of reference conditions and values, NRCAs also report on trends, when appropriate (i.e., when the underlying data and methods support such reporting), as well as influences on resource conditions. These influences may include past activities or conditions that provide a helpful context for understanding current conditions, and/or present-day threats and stressors that are best interpreted at park, watershed, or landscape scales (though NRCAs do not report on condition status for land areas and natural resources beyond park boundaries). Intensive cause-and-effect analyses of threats and stressors, and development of detailed treatment options, are outside the scope of NRCAs.

Due to their modest funding, relatively quick timeframe for completion, and reliance on existing data and information, NRCAs are not intended to be exhaustive. Their methodology typically involves an informal synthesis of scientific data and information from multiple and diverse sources. Level of rigor and statistical repeatability will vary by resource or indicator, reflecting differences in existing data and knowledge bases across the varied study components.

The credibility of NRCA results is derived from the data, methods, and reference values used in the project work, which are designed to be appropriate for the stated purpose of the project, as well as adequately documented. For each study indicator for which current condition or trend is reported, we will identify critical data gaps and describe the level of confidence in at least qualitative terms. Involvement of park staff and National Park Service (NPS) subject-matter experts at critical points during the project timeline is also important. These staff will be asked to assist with the selection of study indicators;



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A NRCA is intended to provide useful science-based information products in support of all levels of park planning.

recommend data sets, methods, and reference conditions and values; and help provide a multi-disciplinary review of draft study findings and products.

NRCAs can yield new insights about current park resource conditions, but in many cases, their greatest value may be the development of useful documentation regarding known or suspected resource conditions within parks. Reporting products can help park managers as they think about near-term workload priorities, frame data and study needs for important park resources, and communicate messages about current park resource conditions to various audiences. A successful NRCA delivers science-based information that is both credible and has practical uses for a variety of park decision making, planning, and partnership activities.

However, it is important to note that NRCAs do not establish management targets for study indicators. That process must occur through park planning and management activities. What a NRCA can do is deliver science-based information that will assist park managers in their ongoing, long-term efforts to describe and quantify a park's desired resource conditions and management targets. In the near term, NRCA findings assist strategic park resource planning[6] and help parks to report on government accountability measures.[7] In addition, although in-depth analysis of the effects of climate change on park natural resources is outside the scope of NRCAs, the condition analyses and data sets developed for NRCAs will be useful for park-level climate-change studies and planning efforts.

NRCA Reporting Products…

- Provide a credible, snapshot-in-time evaluation for a subset of important park natural resources and indicators, to help park managers:
- Direct limited staff and funding resources to park areas and natural resources that represent high need and/or high opportunity situations (near-term operational planning and management)
- Improve understanding and quantification for desired conditions for the park's "fundamental" and "other important" natural resources and values (longer-term strategic planning)
- Communicate succinct messages regarding current resource conditions to government program managers, to Congress, and to the general public ("resource condition status" reporting)

NRCAs also provide a useful complement to rigorous NPS science support programs, such as the NPS Natural Resources Inventory & Monitoring (I&M) Program.[8] For example, NRCAs can provide current condition estimates and help establish reference

6. An NRCA can be useful during the development of a park's Resource Stewardship Strategy (RSS) and can also be tailored to act as a post-RSS project.

7. While accountability reporting measures are subject to change, the spatial and reference-based condition data provided by NRCAs will be useful for most forms of "resource condition status" reporting as may be required by the NPS, the Department of the Interior, or the Office of Management and Budget.

8. The I&M program consists of 32 networks nationwide that are implementing "vital signs" monitoring in order to assess the condition of park ecosystems and develop a stronger scientific basis for stewardship and management of natural resources across the National Park System. "Vital signs" are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values.

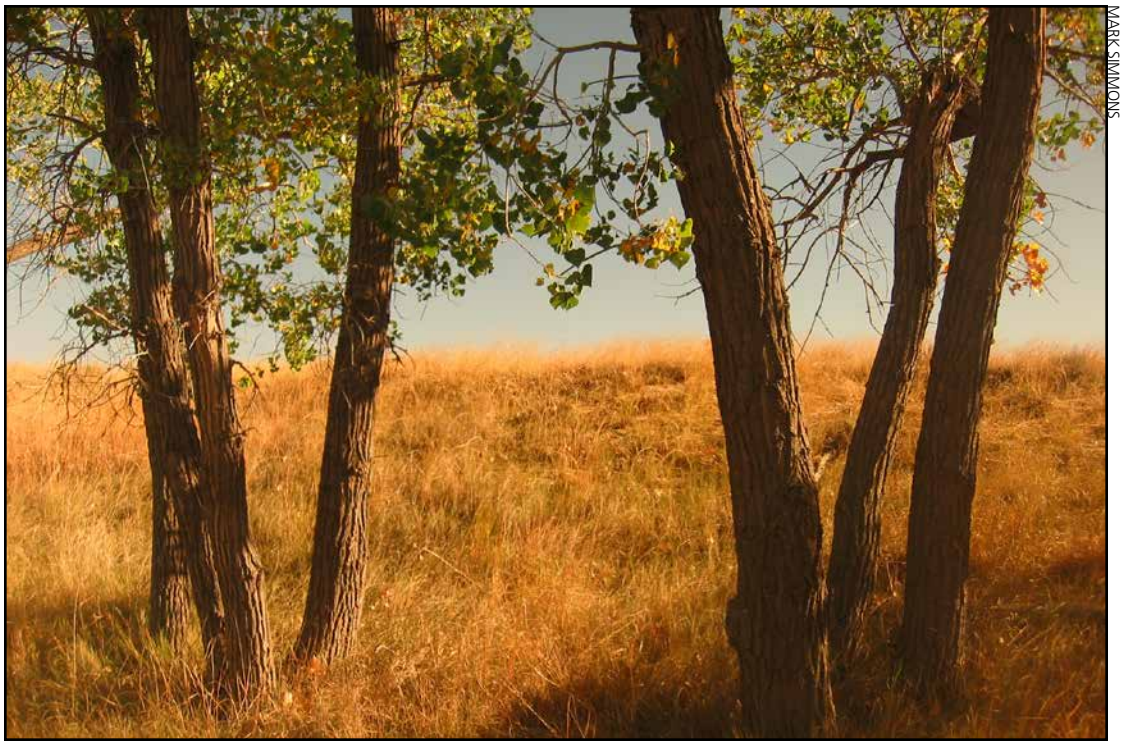


SOPN STAFF

A NRCA uses a variety of data to assess the condition of a park's natural resources.

conditions, or baseline values, for some of a park's vital signs monitoring indicators. They can also draw upon non-NPS data to help evaluate current conditions for those same vital signs. In some cases, I&M data sets are incorporated into NRCA analyses and reporting products.

Over the next several years, the NPS plans to fund a NRCA project for each of the approximately 270 parks served by the NPS I&M Program. For more information on the NRCA program, visit http://www.nature.nps.gov/water/NRCondition_Assessment_Program/Index.cfm.



MARK SIMMONS

Plains cottonwood ***(Populus deltoides) trees are common*** at Sand Creek Massacre NHS.

Chapter 2: Introduction and Resource Setting

2.1. Introduction

2.1.1. Enabling Legislation

Protection was first provided to Sand Creek Massacre National Historic Site on November 7, 2000. Public Law 106-465 was passed by the 106th Congress to protect the area where "on November 29, 1864 a peaceful village of Cheyenne and Arapaho Indians under the leadership of Chief Black Kettle, along Sand Creek in southeastern Colorado territory was attacked by approximately 700 volunteer soldiers commanded by Colonel John M. Chivington and where more than 150 Cheyenne and Arapaho were killed in the attack, most of whom were women, children, or elderly." In addition "the site of the Sand Creek Massacre is of great significance to descendants of the victims of the massacre and their respective tribes, for the commemoration of ancestors at the site, and the site is a reminder of the tragic extremes sometimes reached in the 500 years of conflict between Native Americans and people of European and other origins concerning the land that now comprises the United States." ([U.S. Federal Register Public Law 106-465]. After several years of research and collaboration between tribes, state and federal agencies, affected landowners, and universities, Sand Creek Massacre NHS was formally dedicated and became a unit of the National Park Service in 2007 (NPS-SAND 2013)

2.1.2. Geographic Setting

The Historic Site is located in Kiowa County is about 15 miles northeast of Eads and seven miles north of Chivington on County Road W in southeastern Colorado where it is sparsely populated (Figure 2.1.2-1). The Historic Site is 2,386 acres (965.4 hectares), and the authorized boundary of Historic Site, surrounding the established boundary is in private ownership. The Historic Site is surrounded by agricultural lands and shrub/scrublands (Figure 2.1.2-2).

2.1.3. Visitation Statistics

The Historic Site opened to visitation in 2007, and visitor data tallying began in 2010. The number of visitors for 2010 was 4,063, in

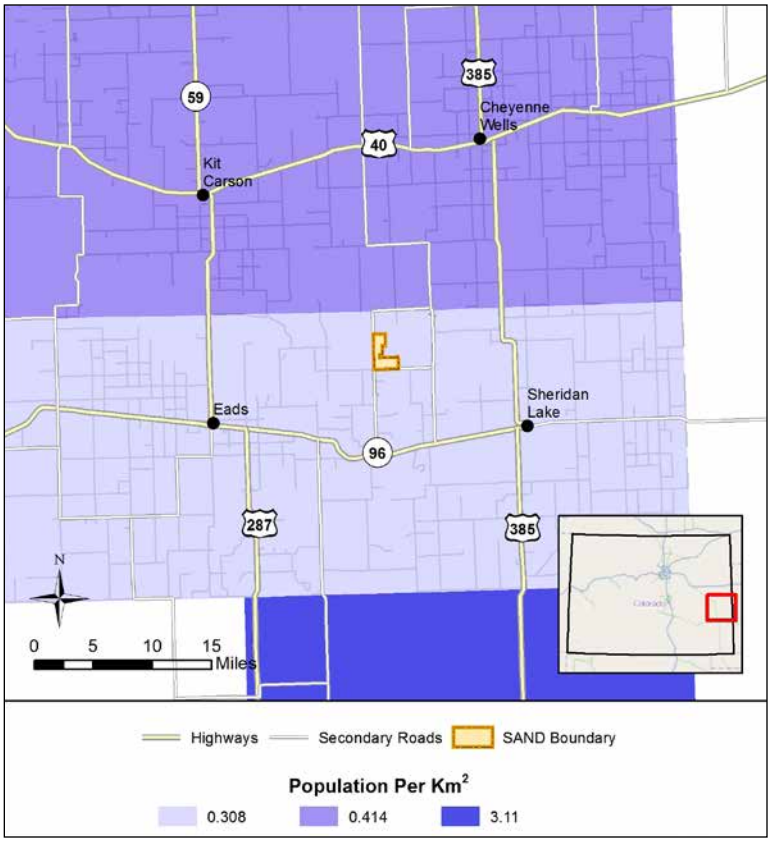


Figure 2.1.2-1. Population density around Sand Creek Massacre NHS.

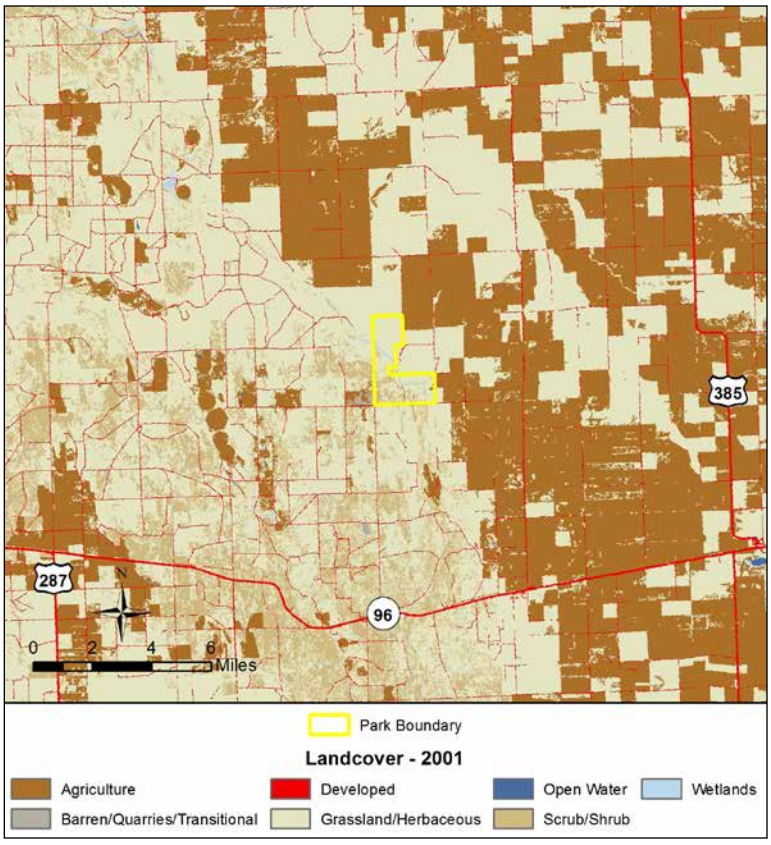


Figure 2.1.2-2. Land use around Sand Creek Massacre NHS.

2011 was 3,935, and in 2012 was 4,384. Data on visitation by month are available for 2010-2012. In every year during this 3-year period, the number of visitors peaked May to October (Figure 2.1.3-1) but the Historic Site is only open between April 1-October 31 annually (NPS Visitor Use Office 2013).

2.2. Natural Resources

A summary of the natural resources at Sand Creek Massacre NHS is presented in section 2.2.1 representing information known prior to the completion of this condition assessment. A myriad of new data were gathered and compiled throughout this assessment process as a result of the meetings, consultations, and literature reviews pertaining to each natural resource topic. Therefore, some of the information presented in section 2.2.1 may have been included in subsequent chapters or omitted depending upon new findings.

2.2.1. Ecological Units and Watersheds

Sand Creek Massacre NHS is primarily composed of shortgrass prairie and sage shrubland. Shortgrass prairies support numerous plant and animal species, including federal and state listed endangered, threatened, and candidate species. Big Sandy Creek, an intermittent stream, crosses the Historic Site.

The Historic Site is located in the Arkansas-White-Red watershed region of the United States and is located within the Big Sandy Creek subwatershed (Figure 2.2.1-1). The subwatershed drains an approximate area of 1,890 square miles (USGS 2013).

2.2.2. Resource Descriptions

(All resource background text excerpted from Neid et al. 2007 is italicized in the following section.)

Geology and Soils

Surficial geology of Sand Creek Massacre, as with much of Colorado's eastern plains, is relatively recent; it is dominated by Quaternary deposits with pockets of late Cretaceous layers (Coffin 1967). Underlying this recent surface is a half billion years worth of accumulated marine sediments and capped with sediments and

aeolian deposits. Thousands of feet of marine layers were deposited when the continental interior was under an extensive, shallow, inland sea (Paleozoic to Mesozoic; 570-70 million years ago); these layers were piled atop ancient bedrock that is among the oldest in the continent. The vast inland sea was drained by continental uplift and climate changes, exposing the expansive, nearly flat surface of the former sea floor to weathering and erosion (Trimble 1980).

In this region of the temperate shortgrass steppe, calcification is the predominant soil forming process (Bailey et al. 1994). Soils tend to be rich in base ions and have an excess of precipitated calcium carbonate because climate conditions are too dry to leach the ions from the top horizons. Soils are typically mollisols although with relatively low organic matter content due to relatively sparse vegetation of the shortgrass steppe. Salinization occurs in poorly drained areas where evaporation brings salts to the surface (Chapman et al. 2006). Examples of such salinization occur in the small, localized bare spots in swales in the sandhills on the southwest side of the Historic Site.

Soils at the Historic Site are distinctly different on either side of Big Sandy Creek. They are generally categorized as loamy to the north and east of the drainage on gently rolling upland plains and sandy to the south and west where they blanket ancient sandhills (Anderson et al. 1981). In bottomlands along Big Sandy Creek, fluvaqent soils form a mixed mosaic with sands and loams that developed from a mix of alluvial and aeolian deposits in a series of ancient alluvial terraces.

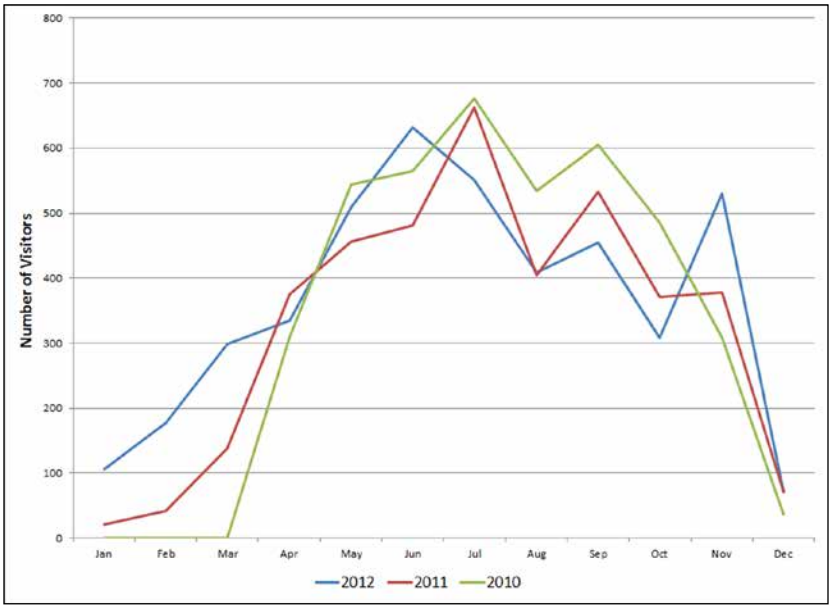


Figure 2.1.3-1. Visitation numbers from 2010 to 2012.

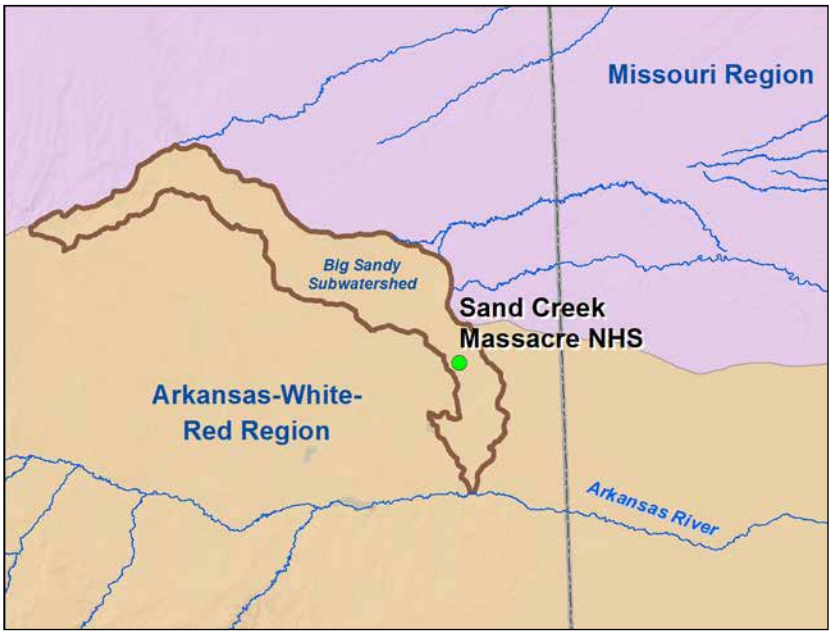


Figure 2.2.1-1. Sand Creek Massacre NHS is located in the Arkansas-White-Red watershed region.

Hydrology

Big Sandy Creek is a typical intermittent stream of semiarid climates (Labbe and Fausch 2000). There are short reaches where there is perennial flow in Big Sandy Creek including a stretch on SAND where water input from the tributary that bisects the Chivington Ditch from the northeast maintains surface water. Outside of these areas, surface water is contained in small, isolated pools during most of the year. As also is typical of streams in the region, Big Sandy Creek can have a flashy hydrograph in response to brief, heavy rain storms within the watershed. Flooding from localized thunderstorms can be severe, but is generally brief due to rapid absorption in sandy soils (Labbe and Fausch 2000).

Air Quality

Sand Creek Massacre NHS is designated as a Class II air quality area. Prior to this NRCA no air quality data have been analyzed for the Historic Site.

Wildlife

The Historic Site provides a small oasis of shortgrass prairie habitat that is surrounded by agricultural fields and sand sagebrush rangeland. It is habitat for a wide diversity of wildlife associated with shortgrass prairie, such as black-tailed prairie dogs (Cynomys ludovicianus ludovicianus), shortgrass prairie birds, raptors, and pronghorn (Antelocapra americana) (Sovell 2006) and for more generalist wildlife species such as mule deer (Odocoileus hemionus). The region also has an established population of non-native, feral hogs (Sus scrofa), (Hartman 2006). [Note from Historic Site staff: Both *Odocoileus hemionus* and *Sus scrofa* haven't been observed since 2007 (K. Zimmermann, Chief of Resources and Maintenance, pers. comm.).

Of the wildlife species at the Historic Site, prairie dogs have the greatest influence on vegetation. Black- tailed prairie dog towns historically covered millions of acres within the Great Plains, especially in the shortgrass prairie. Prairie dogs dig extensive burrow systems in their towns. They graze the surrounding vegetation, keeping it clipped short, creating the appearance of a mowed lawn, or heavily grazed rangeland. This behavior is presumably to improve their ability to detect predators. Preferential grazing alters plant species composition within a few years after colonization (Hoagland 1995). While plant cover decreases overall, annual forbs become more abundant due to increased small-scale disturbance from digging. Prairie dog towns can expand and contract over time as prairie dog populations fluctuate. Their towns, however, provide habitat for a wide diversity of animal species that utilize them, such as badgers (Taxidea taxus), eastern cottontails (Sylvilagus floridanus), coyotes (Canis latrans), grasshopper mice (Onychomys leucogaster), swift fox (Vulpes velox), pronghorn antelope, striped skunks (Mephitis mephitis), white-tailed deer (Odocoileus virginianus), cattle, thirteen-lined ground squirrels (Spermophilus tridecemlineatus), black-tailed jackrabbits (Lepus califonicus), barred tiger salamanders (Ambystoma tigrinum), plains spadefoot toads (Scaphiopus bombifrons), Great Plains toad (Bufo cognatus), Woodhouse's toad (Bufo woodhousii), prairie rattlesnakes (Crotalis viridis), western plains garter snakes (Thamnophis radix), Texas horned lizards (Phrynosoma cornutum), ornate box turtles (Terrapene ornata) (Lomolino and Smith 2003), and other shortgrass prairie birds (Smith and Lomolino 2003). Prairie dog towns also attract aerial predators such as hawks, eagles, and falcons.

Shortgrass prairie is home to several candidates for federal endangered or threatened species status and several State of Colorado listed species(Sovell et al. 2008). The pools of the Big Sandy Creek running through the Historic Site contain suitable habitat for the Arkansas darter (*Etheostoma cragini*), which is a species of concern (with numerous rankings and designations by conservation organizations) but haven't been observed at the Historic Site. However, the Plains killfish *(Fundulus zebrinus)* has been observed.

Rare Invertebrates

Kondraitieff and Durfee (2010) conducted a study at the Historic Site to document aquatic insects found in the Big Sandy Creek. A total of 107 distinguishable taxa were collected representing six orders and 27 families. The Bleached Skimmer (*Libellula composita* Hagen) is a localized species of eastern Colorado and regionally uncommon in Colorado, however, it was common at the Historic Site. Another uncommon species throughout Colorado, but found at the Historic Site, was the Black-fronted Forktail (*Ischnura denticollis* Burmeister), which is a damselfly of western marshes and springs.

Vegetation

Vegetation at the Historic Site is a mosaic of sand sagebrush shrubland and shortgrass prairie bisected by a corridor of riparian vegetation. Sand sagebrush occupies the sandhills to the south and west of Big Sandy Creek within the Historic Site and shortgrass prairie generally characterizes the loamier north and east side. The riparian corridor is a mosaic of cottonwood woodland, mesic grassland, and wet meadow surrounding a narrow, braided stream channel.

Night Sky and Soundscape

Formal studies on the Historic Site's night sky and soundscape have been conducted

by the NPS Natural Sounds and Night Skies Division. Both indicate that the Historic Site is situated within a relatively quiet and rural area.

2.2.3. Resource Issues Overview

(Excerpted from National Park Service (2009).

The natural environment and availability of resources has impacted the lifestyles of humans who have used the area for the past 8,000–10,000 years. The site and surrounding area have been affected by hunting, grazing, cultivation, water diversion, development, introduction of non-native species, and extirpation (local extinction) of native species such as pronghorn antelope and bison. The landscape of Sand Creek Massacre Historic Site is a record of human relationships with the natural environment, the contrasting values of American Indians and Euroamericans, and their competition for limited resources. The continued protection and preservation of these resources contributes to our knowledge of the changing diversity of the Plains ecosystem, its biological communities and its human stories.

2.3. Resource Stewardship

2.3.1. Management Directives and Planning Guidance

In addition to NPS staff recommendations, the Washington (WASO) level programs guided the selection of key natural resources for this condition assessment. This included Southern Plains Inventory and Monitoring Network (SOPN) Program, Air Resources Division for air quality, and the Natural Sounds and Night Skies Program for the soundscape and night sky sections. In addition, NPScape data, developed by the Inventory and Monitoring's Washington Office, were used in the viewshed analysis.

SOPN Program

In an effort to improve overall park management through expanded use of scientific knowledge, the Inventory & Monitoring (I&M) Program was established to collect, organize, and provide natural resource data as well as information derived from data through analysis, synthesis, and modeling (NPS 2011). The primary goals of the I&M Program are to:

- inventory the natural resources under NPS stewardship to determine their nature and status;
- monitor park ecosystems to better understand their dynamic nature and condition and to provide reference points for comparisons with other altered environments;
- establish natural resource inventory and monitoring as a standard practice throughout the National Park System that transcends traditional program, activity, and funding boundaries;
- integrate natural resource inventory and monitoring information into NPS planning, management, and decision making; and
- share NPS accomplishments and information with other natural resource organizations and form partnerships for attaining common goals and objectives (NPS 2011).

To facilitate this effort, 270 parks with significant natural resources were organized into 32 regional networks. Sand Creek Massacre NHS is part of the SOPN, which includes ten additional parks. Through a rigorous multi-year, interdisciplinary scoping process, each network selected a number of important physical, chemical, and/or biological elements and processes for long-term monitoring. These ecosystem elements and processes are referred to as 'vital signs', and their respective monitoring programs are intended to provide high-quality, long-term information on the status and trends of those resources. For the SOPN, notable core vital signs were identified. Inventories on vascular plants, mammals, reptiles, birds, and geologic resources have been completed and monitoring on birds, exotic plants, and grassland communities is currently underway

Resource Stewardship Strategy

Each national park is encouraged to develop a Resource Stewardship Strategy (RSS) as part of the park management planning process. Indicators of resource condition, both natural and cultural, are selected by the

park. After each indicator is chosen, a target value is determined and the current condition is compared to the desired condition. The Historic Site has a draft RSS that is currently in the review phase. Management plans may then be developed based upon information from the RSS and NRCA to outline actions to be taken over the next 15 to 20 years that will help achieve or maintain the desired condition(s) for each indicator.

2.3.2. Status of Supporting Science

Available data and reports varied significantly depending upon the resource topic. The existing data used for each indicator to assess condition or to develop reference condition are described in each indicator summary in chapter four. Part of SOPN's mission is to collect, manage, analyze, and report long-term ecological data to support each park in determining the status, condition, and trend of important natural resources (USDI NPS 2008). In addition to data from the SOPN Program and research by other scientists and programs, subject matter experts provided significant information pertaining to soils, riparian habitat, and grassland ecology. Washington level programs, including night sky, soundscape, and air quality also provided a wealth of information for this NRCA.

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Grasslands field meeting at Sand Creek Massacre NHS.

Chapter 3: Study Scoping and Design

This NRCA is a collaborative project between the Sand Creek Massacre NHS staff and the SOPN, both of the NPS. Stakeholders in this project include the Historic Site's natural resource managers and management staff and SOPN staff. The purpose of the condition assessment is to provide a "snapshot-in-time" evaluation of the condition of a select set of Historic Site natural resources that were identified and agreed upon by the project team. Project findings will aid Historic Site staff in the following objectives:

- Develop near-term management priorities.
- Engage in watershed or landscape scale partnership and education efforts.
- Conduct park planning (e.g., General Management Plan (GMP), compliance, Resource Stewardship Strategy, resource management plans).

The approach we used to select natural resources was to assess the fundamental and important values of the Historic Site as well as to consider broader natural resources as identified by the NPS' Natural Resource Program Center. The resources assessed are limited to natural-based topics, but cultural resources were also taken into consideration within the context of the chosen natural resources.

3.1. Preliminary Scoping

The selection of resources to assess resulted from meetings and subsequent discussions. For a complete list of team members, please refer to Appendix A.

These meetings and discussions focused on:

1. Confirming the purpose of the Historic Site and its related significance statements and related values.
2. Identifying important natural and cultural resources and concerns for each topic.
3. Identifying data sources and gaps for each resource topic.

Certain constraints were placed on this NRCA, including the following:

- Condition assessments are conducted using existing data and information.

- Identification of data needs and gaps is driven by the project framework categories.

- A preliminary study framework was developed as a result of the meetings and discussions, which listed the chosen resources and the degree of assessment (e.g., full or limited) based upon existing data and information.

Specific project expectations and outcomes included the following:

- For key natural resource components, consolidate available park data, reports, and spatial information from appropriate sources including: Historic Site resource staff, scientific literature, NatureBib, NPSpecies, Inventory and Monitoring data, and available third-party sources. Enlist the help of subject matter experts for each resource topic when appropriate and feasible (refer to Appendix A for subject matter expert list).

- Define an appropriate description of reference condition for each of the key natural resource components and indicators so statements of current condition can be developed for the NRCA report.

- Where applicable, develop GIS products and graphic illustrations that provide spatial representation of resource data, ecological processes, resource stressors, trends, or other valuable information that can be better interpreted visually.

- Conduct analysis of specific existing data sets to develop descriptive statistics about key natural resource indicators.

- Discuss the issue of key natural resource indicators that are not contained within the Historic Site or controlled directly by Historic Site management activities (e.g., viewshed condition). There are important stressors that impact key natural resource components in the Historic Site but are not under NPS jurisdiction.

Historic Site natural resource staff participated in on-site meetings. Historic Site staff reviewed interim and final products. Historic Site staff, I&M staff, and additional writer/editors data mined information for each assigned resource topic.

3.2. Study Design

3.2.1. Indicator Framework, Focal Study Resources and Indicators

The Historic Site's NRCA utilizes an assessment framework adapted from "The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States", by the H. John Heinz III Center for Science, Economics and the Environment. This framework was endorsed by the National NRCA Program as an appropriate framework for listing resource components, indicators/measures, and resource conditions.

Each NRCA project represents a unique assessment of key natural resource components that are important to the specific park that is being assessed. As a result, the project framework is developed by the project participants to reflect the key resources of the park. For the purpose of this NRCA, 14 key Historic Site resources were identified and are listed under the "Resource" column in Table 3.2.1-1. This list of focal study resources is not all inclusive of every natural resource at the Historic Site, but it includes natural resources and processes that were of greatest concern at the time of this assessment.

Reference conditions were identified with the intent of providing a benchmark to which the current condition of each indicator/measure could be compared. Generally, this condition represents a historical reference in which modern human activity and disturbance were not major drivers of population and ecological processes. Attempts were made to utilize existing research and documentation to identify reference conditions; however, many of the indicators lack a quantifiable reference condition according to literature

Table 3.2.1-1. Final Sand Creek Massacre NHS Natural Resource Condition Assessment Framework

Resource	Assessment Level	Indicators and Measures
I. Landscape Condition Context		
Viewshed	Full Assessment	• Scenic and Historic Integrity • Intactness • Conspicuousness of noncontributing features • Housing density • Road density
Night Sky	Full Assessment	• Bortle Dark-Sky Scale • Limiting magnitude • Sky brightness
Soundscape	Full Assessment	• Amount of acoustical environment comprised of natural sounds vs. anthropogenic noise • Are types of sounds consistent with designated park uses? • Characteristics of anthropogenic noise
II. Supporting Environment		
Air Quality	Full Assessment	• Visibility haze index • Level of ozone • Atmospheric wet deposition in total N and total S
Geology	Limited Assessment	• No indicators or measures were identified
Surface Water	Limited Assessment	• Water Quality (temperature, specific conductance, pH, dissolved oxygen, and turbidity)
Groundwater	Limited Assessment	• Change in groundwater level
III. Biological Integrity		
Vegetation		
Riparian Habitat	Full Assessment	• Hydrology (5 indicators) • Vegetation (7 indicators) • Erosion/deposition (5 indicators)
Grasslands	Full Assessment	• Hydrology Soil/Site Stability and Hydrologic Function (10 Indicators) • Biotic Integrity (5 indicators)
Exotic Plants	Full Assessment	• Significance of impact • Feasibility of control • Proportion of high priority blocks infested • Proportion of interior plots infested • Distribution of high priority species
Wildlife		
Landbirds	Full Assessment	• Species occurrence: temporal context • Species occurrence: spatial context • Species occurrence: conservation context
Prairie Dog	Limited Assessment	• Area occupied and density of prairie dogs
Rare Vertebrates	Limited Assessment	• Presence/absence of vertebrate species
Aquatic Invertebrates	Limited Assessment	• Presence/absence of invertebrate species

and data reviewed for this project. When a specific reference condition for the Historic Site resources was unknown, an attempt was made to include state and federal standards or data from other relevant locations in order to provide some context for interpreting condition.

3.2.2. Reporting Areas

Since the Historic Site does not have an approved GMP, the reporting area was treated as one unit and encompassed the entire acreage within the Historic Site's established boundary (vs. authorized boundary). We will be referring to the established boundary

throughout the remainder of this document unless otherwise noted. Due to the nature of some of the focal study resources, areas outside of the Historic Site's boundary were assessed to determine overall condition within the Historic Site (e.g., viewshed, air quality).

3.2.3. General Approach and Methods

This study involved reviewing existing literature and data for each of the resources listed, and, where appropriate, analyzing the data to provide summaries or to create new spatial representations. After gathering data regarding current condition of indicators and measures, a qualitative statement was developed comparing the current condition(s) at the Historic Site to the reference condition(s) when possible.

Data Mining

Data and literature were found in multiple forms: NPS reports and monitoring plans (park, regional, and national level), other reports from various state and federal agencies, published and unpublished research documents, non-governmental organization reports, databases, and tabular data. Spatial data were provided by the Historic Site, the SOPN, and by the Natural Resource Program Center. Data and literature acquired throughout the data mining process were inventoried and analyzed for thoroughness, relevancy, and quality pertaining to the indicators identified in the project framework. All reasonably accessible and relevant data were used to conduct this assessment.

Subject Matter Experts

Several researchers and subject matter experts were consulted while developing this assessment. Consultations ranged from on-site visits to personal communication, and reviews of resource sections. A full list of the team of experts can be found in Appendix A.

Data Analyses and Development

Data analysis and development/writing tasks were performed for specific resources based on the data mining process and recommendations provided by NPS staff. Data analyses and development were resource specific, and the methodology for individual analyses can be found within each section of chapter four.

Geographic Information System (GIS) technology was utilized to graphically depict the status and distribution of considered resources when possible.

Final Assessments

Final assessments were made by incorporating comments provided by subject matter experts, reviewers, and Historic Site staff during the review of draft chapters. Additionally, continued contact with Historic Site staff to address questions and comments pertaining to each resource topic was maintained throughout the data analysis and report writing phase to ensure accurate representation of staff knowledge. The final assessments represent the most relevant and timely data available for each resource topic based on the recommendations and insight provided by Historic Site staff, researchers, subject matter experts, and assessment writers.

Indicator/Measures Assessment Format

Indicator assessments are presented in a standard format that is consistent with *State of the Park* reporting (NPS 2012). The major components are as follows:

The condition/trend/level of confidence graphic provides a visual representation for each resource indicator and intended to give readers a quick interpretation of the authors' assessments of condition. The level of confidence ranges from high-low and indicates how confident we are with the data used to determine condition. The written statements of condition, located under the "*Condition and Trend*" heading in each resource topic section, provides a more in-depth description of each indicator and associated measure(s)' condition. Figure 3.2.3-1 shows the condition/trend/confidence level scorecard used to describe each indicator/measure.

Circle colors provide indication of condition or concern. Red circles signify that a resource is of significant concern; yellow circles signify

Condition Status		Trend in Condition		Confidence in Assessment	
	Warrants Significant Concern		Condition is Improving		High
	Warrants Moderate Concern		Condition is Unchanging		Medium
	Resource is in Good Condition		Condition is Deteriorating		Low
	An open (uncolored) circle indicates that current condition is unknown or indeterminate; this condition status is typically associated with unknown trend and low confidence				

Figure 3.2.3-1. Condition, trend, and level of confidence key used in the Sand Creek Massacre NHS NRCA.

that a resource is of moderate concern; and green circles denote that an indicator is currently in good condition. A circle without any color, (which are always associated with the low confidence symbol-dashed line), signify that there is insufficient information to make a statement about concern or condition of the indicator, therefore unknown.

Arrows inside the circles signify the trend of the indicator/measure condition. Upward pointing arrows signify that the indicator is improving; right pointing arrows signify that the indicator's condition is currently unchanging; downward pointing arrows indicate that the indicator's condition is deteriorating. No arrow denotes that the trend of the indicator's condition is currently unknown. Figure 3.2.3-2 is an example of a final condition graphic used in the indicator assessments.

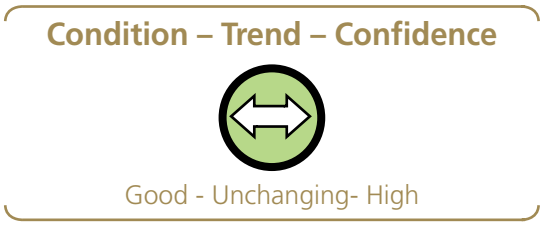


Figure 3.2.3-2. An example of a good condition, unchanging trend, and high confidence level in assessment graphic used in NRCAs.

Background and Importance

This section provides information regarding the relevance of the resource to the Historic Site. This section also explains the characteristics of the resource that help the reader understand subsequent sections of the document.

Data and Methods

This section describes the existing datasets used for evaluating the indicators/measures. Methods used for processing or evaluating the data are also discussed where applicable. The indicators/measures are listed in this section as well, describing how we measured or qualitatively assessed the natural resource topic.

Reference Conditions

This section explains the reference conditions that were used to evaluate the current condition for each indicator. Additionally, explanations of available data and literature that describe the reference conditions are located in this section.

Condition and Trend

This section provides a summary of the condition and trend of the indicator/measure at the Historic Site based on available literature, data, and expert opinions. This section highlights the key elements used in defining the condition and trend designation, represented by the condition/trend graphic, located at the beginning of each resource topic.

The level of confidence and key uncertainties are also included in the condition and trend section. This provides a summary of the unknown information and uncertainties due to lack of data, literature, and expert opinion,

as well as our level of confidence about the presented information.

Sources of Expertise
Individuals who were consulted for the focal study resources are listed in this section. A short paragraph describing their background is also included.

Literature Cited
This section lists all of the referenced sources. A DVD is included in the final report with copies of all literature cited unless the citation was from a book. When possible, links to websites are also included.

3.3. Literature Cited

The H. John Heinz III Center for Science, Economics and the Environment. 2008. The State of the Nation's Ecosystems 2008: Measuring the Lands, Waters, and Living Resources of the United States. Washington, D.C.

National Park Service. 2012. A Call to Action: Preparing for a Second Century of Stewardship and Engagement. Washington, D.C. 28pp

Chapter 4: Natural Resource Conditions

In this chapter, we present the background and importance, methods, and condition assessment for each focal study resource that we considered for Sand Creek Massacre NHS. In many cases, we did not have a quantitative measure for the indicators but tried to present meaningful categorical measures qualitatively that reflect the condition. We also explained why each indicator was chosen and what we considered as a good, moderate or significant concern reference condition for each indicator. We provide a summary of all focal study resource indicators and their page numbers for explanations of our methods and natural resource conditions in Table 4.1.

Table 4.1. Page numbers where the description, methods, and condition for each indicator are presented within this chapter.

Resource	Indicator	Description/ Methods	Condition
I. Landscape Condition Context			
Viewshed	Scenic and Historic Integrity	22	30
	Intactness	24	30
	Conspicuousness of noncontributing features	25	33
	Housing and road density	28	32
Night Sky	Anthropogenic Light Ratio	40	45
	ZenithSky Brightness	41	45
	Limiting magnitude	41	45
	Bortle Dark-Sky Scale	41	45
Soundscape	Amount of acoustical environment comprised of natural sounds vs. anthropogenic noise	54	55
	Are types of sounds consistent with designated park uses?	54	55
	Characteristics of anthropogenic noise	54	55
Air Quality	Visibility haze index	65	66
	Level of ozone	65	67
	Atmospheric wet deposition in total N and total S	66	67
Geology	No indicators or measures were identified		
Surface Water	Water Quality (temperature, specific conductance, pH, dissolved oxygen, and turbidity)	75	76
Groundwater	Change in Groundwater Level	81	82
II. Biological Integrity			
Vegetation			
Riparian Habitat	Hydrology (5 indicators)	87	91
	Vegetation (7 indicators)	88	94
	Erosion/Deposition (5 indicators)	89	95
Grasslands	Hydrology Soil/Site Stability and Hydrologic Function (10 Indicators)	103	109
	Biotic Integrity (5 indicators)	104	109

Table 4.1. Page numbers where the description, methods, and condition for each indicator are presented within this chapter (cont.).

Resource	Indicator	Description/ Methods	Condition
Exotic Plants	Significance of impact	124	126
	Feasibility of control	124	128
	Proportion of high priority blocks infested	124	128
	Proportion of park grid plots infested	125	129
	Distribution of highly ranked species	126	130
Wildlife			
Landbirds	Species Occurrence - Temporal Context	138	145
	Species Occurrence - Spatial Context	139	146
	Species Occurrence - Conservation Context	139	146
Prairie Dog	Area occupied and density of prairie dogs	158	159
Rare Vertebrates	Presence/absence of vertebrate species	167	168
Aquatic Invertebrates	Presence/absence of invertebrate species	169	169

4.1. Viewshed

Indicators/Measures

- Scenic and Historic Integrity
- Intactness
- Conspicuousness of noncontributing features
- Housing density
- Road density

Condition – Trend - Confidence



Good – Unchanging - High

4.1.1. Background and Importance

The conservation of scenery is established in the National Park Service (NPS) Organic Act ("… to conserve the scenery and the wildlife therein…"), reaffirmed by the General Authorities Act, as amended, and addressed generally in the NPS Management Policies (Section 1.4.6 and 4.0) (Johnson et al. 2008). Although no management policy currently exists exclusively for scenic or viewshed management and preservation, parks are still required to protect scenic and viewshed quality as one of their most fundamental resources. According to Biel (2005), aesthetic conservation, interchangeably used with scenic preservation, has been practiced in the NPS since the early twentieth century. Aesthetic conservation strove to protect scenic beauty for park visitors to better experience the values of the park. The need for scenic preservation management is as relevant today as ever, particularly with the pervasive development pressures that challenge park stewards to conserve scenery today and for future generations.

Sand Creek Massacre National Historic Site commemorates the Sand Creek Massacre that occurred November 29, 1864. The massacre resulted when ~765 U.S. Volunteer Cavalry attacked and killed over ~200 Cheyenne and Arapaho people, mainly women, children, and the elderly, who were peacefully encamped along Big Sandy Creek. The massacre was a dynamic event that took place over an area approximately 5.5 miles long and 2 miles wide. Sand Creek Massacre National Historic Site recognizes the significance of this massacre and that the site has sacred significance to the Cheyenne and Arapaho tribes, particularly those who are descended from victims and survivors of the massacre. Within this context, the cultural landscapes and viewshed have been identified as one of the fundamental resources and values for the site (NPS 2012a) (Figure 4.1.1-1).



DAVID ZETTNER

Figure 4.1.1-1. View from near the memorial overlook at Sand Creek Massacre National Historic Site.



Figure 4.1.1-2. One of the values of a viewshed, particularly one with such historic significance, is the potential to visualize that site as it once might have been to gain a "sense of place" in that historic context.

Visitor Experience

Inherent in virtually every aspect of this assessment is how features on the visible landscape influence the enjoyment, appreciation, and understanding of the Historic Site by visitors. The indicators we use for condition of the viewshed are based on studies related to perceptions people hold toward various features and attributes of the viewsheds. We also focus on how the historic integrity of the viewshed enhances the opportunity for visitors to better understand the historical significance that the Historic Site had in shaping our country.

From a cultural and historical perspective, the views are not just about the scenery, but rather an important way to better understand the massacre at Sand Creek Massacre NHS. Visualizing the massacre as it played out on the landscape is a critical part of the visitor experience (Figure 4.1.1-2). Views of landscape features are interpreted at the Historic Site, including: how the massacre unfolded, encampments, escape paths, and way of life at the time of the massacre. Being able to experience and see these features in a condition similar to when the massacre took place not only enhances understanding about the details of the massacre, but also creates a personal and emotional response by interacting with the landscape.

4.1.2. Data and Methods

Viewsheds are considered in this assessment within two interrelated contexts: natural scenic integrity and historic integrity. Impacts that degrade one aspect likely degrade the other as well. For example, modern structures or roadways visible on the landscape not only detract from the natural scenic integrity of the viewshed, but also diminish the sense of place that a historically authentic landscape evokes. Depending on the context, scenic and historic integrity may be distinct, or there may be so little practical difference that they are the same. In the case of Sand Creek Massacre National Historic Site, there is so much overlap that we treat them together. We qualitatively assess how features on the landscape contribute (or not) to the scenic and historic integrity of the site.

Indicators/Measures

Scenic and Historic Integrity

The overall indicator of viewshed condition we use in this assessment is a combination of scenic and historic integrity. For this overall indictor we used two ground-based measures from two key vantage points as well as two Geographic Information System (GIS)-based measures, all of which are described in greater detail below.

Scenic integrity is defined as, the state of naturalness or, conversely, the state of disturbance created by human activities or alteration (USFS 1995). This focuses on the features of the landscape related to human influence.

Historic integrity is the authenticity of a site's historic identity, evidenced by the survival of physical characteristics that existed during its historic period. Historic integrity is based on those features of the cultural and natural landscape, from the perspective of an observer, that contribute to the sense of place and enhance the visitor experience. In this assessment, we focus on those features that have a visual impact and contribute to the story of the Massacre at Sand Creek. We evaluate features as contributing, enhancing the scenic and historic features of the landscape, or noncontributing, detracting from the scenic and historic integrity.

We measure scenic and historic integrity using measures from two primary perspectives: (1) ground observation from key vantage points using panoramic images, and (2) an aerial perspective using GIS representation. Our ground-based assessment focuses on specific man-made features that can be seen from key vantage points and whether or not those features are contributing or noncontributing to the scenic and/or historic integrity of the view. For noncontributing features, we further assess the characteristics that make them more or less conspicuous; which influences the level of impact that they might have. In contrast, our GIS-based measures focus on housing density and road density within the Historic Site, as well as to augment the assessment by providing the spatial orientation of key features.

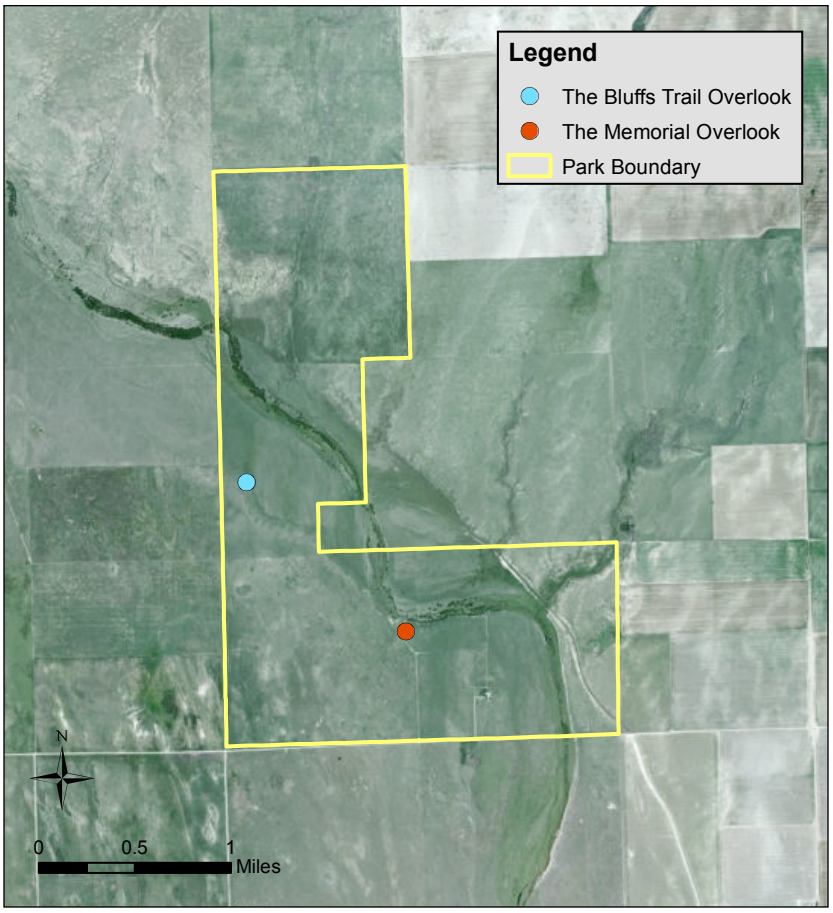


Figure 4.1.2-1. The two key vantage points used in this assessment .

Ground-based Measures of Integrity from Specific Vantage Points

We used two primary measures to assess scenic and historic integrity based on specific features on the landscape that can be seen from key vantage points. These measures are intactness of the view and the conspicuousness of noncontributing features, both of which are described in greater detail below. Each of these were assessed from two key vantage points where most visitors view the landscape as part of their experience at the Historic Site.

Viewshed Vantage Points

The two main vantage points within the Historic Site used in this analysis were *The Memorial Overlook* and *The Bluffs Trail Overlook* (Figure 4.1.2-1). Both of these sites either currently receive, or are expected to receive, high visitation and the views from these points play a major role in the experience of visitors, both for their scenic quality as well as the historic context.

The Memorial Overlook – The Memorial Overlook is probably the most visited location within the site and its views are by design intended to capture both the scenic and historic quality of the site. This vantage point provides views of the massacre site, the cavalry's approach, as well as the Cheyenne-Arapaho's escape routes (Figure 4.1.2-2).

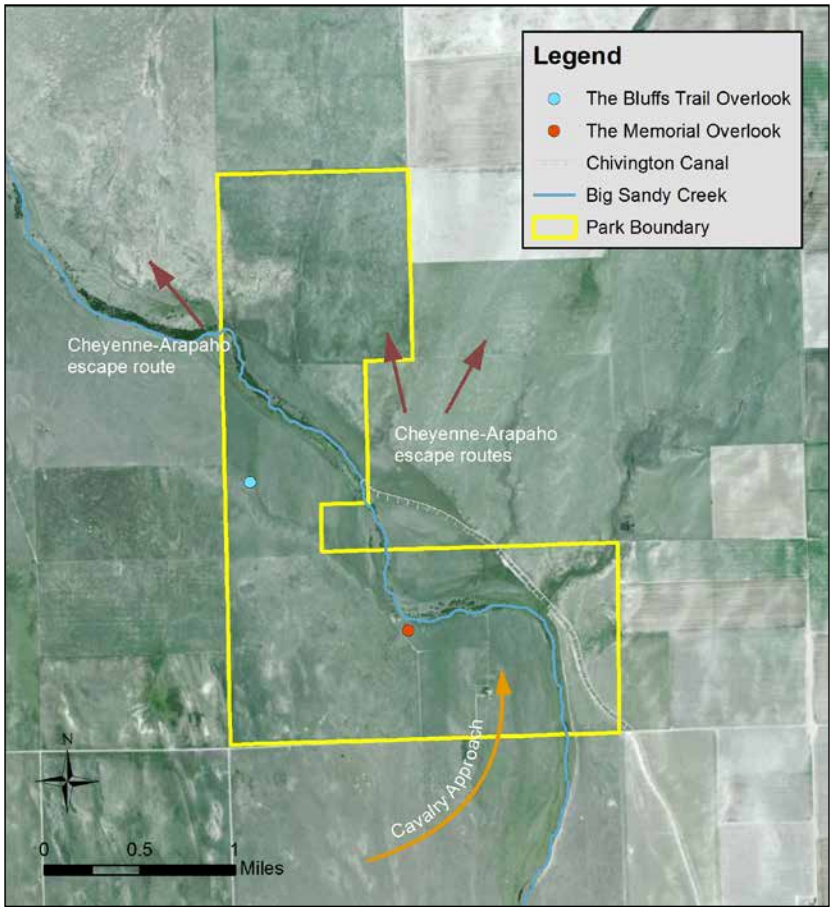


Figure 4.1.2-2. Prominent contributing historic features within view of one or more key vantage point.

The Bluffs Trail Overlook – The Bluffs Trail Overlook is a proposed site to the northwest of the Memorial Overlook. This site has less of a view of the cavalry's approach and the main encampment site, especially given the growth of cottonwood tress since the massacre; but it probably has a better view of the primary Cheyenne-Arapaho escape paths.

Ancillary Views

We used the two key vantage points described above because they are sites that currently receive, or are expected to receive, high levels of visitation and where the viewshed is an essential component of the visitor's experience both because of the scenic quality, as well as the "sense of place" in an historic context. These are however not the only vantage points that are important to the telling the story of the Sand Creek Massacre. These additional views were not included in the assessment with respect to applying our full measures of integrity, but have a important historic contexts and implications to Historic Site management.

Indicators/Measures

Intactness

The extent of intactness provides a measure of the degree to which the viewshed is unaltered from its original (reference) state, particularly the extent to which intrusive or disruptive elements may diminish the character of the scene (USFS 1995, Johnson et al. 2008).

We used a series of panoramic images to portray the viewshed from an observer's perspective from each vantage point. These images were taken using a Canon PowerShot digital camera and the GigaPan Epic 100 system, a robotic camera mount coupled with stitching software (Figure 4.1.2-3). A series of images are automatically captured and the individual photographs are stitched into a single high-resolution panoramic image. These photographs provided a means of illustrating the indicators related to viewshed integrity.

We recognize that visitor perceptions of an altered landscape are highly subjective, and there is no completely objective way to measure this. Research has shown, however, that there are certain landscape types and characteristics that people tend to prefer over others. In general, there is a wealth of research demonstrating that people tend to prefer natural over human-modified landscapes (Zube et al. 1982, Kaplan and Kaplan 1989, Sheppard 2001, Kearny et al. 2008, Han 2010). We believe this is especially true of visitors to national parks. Therefore, natural appearance or a rural setting is considered consistent with the goals of scenic integrity and obvious human-altered components of the landscape (e.g., roads, buildings, powerlines, and other features) are considered to detract from the scenic and historic character of the viewshed.

Despite this generalization for natural landscape preferences, studies have shown that not all human-made structures or features have the same impact on visitor preferences. Visitor preferences can be influenced by a variety of factors including



Figure 4.1.2-3. The GigaPan system takes a series of images that are stitched together to create a single panoramic image.

cultural background, familiarity with the landscape, and their environmental values (Kaplan and Kaplan 1989, Virden and Walker 1999, Kaltenborn and Bjerke 2002, Kearney et al. 2008). .

Indicators/Measures

Conspicuousness of Noncontributing Features

Substantial research has demonstrated that human-made features on a landscape are perceived more positively when they are considered in harmony with the landscape (e.g., Kaplan and Kaplan 1989, Gobster 1999, Kearney et al. 2008). For example, Kearney et al. (2008) showed that survey respondents tended to prefer development that blended with the natural setting through use of colors, smaller scale, and vegetative screening. For this indicator, we focused on four characteristics, or groups of characteristics, that have been demonstrated to contribute to the conspicuousness of man-made features: (1) distance from a given vantage point, (2) size, (3) color and shape, and (4) movement and noise. A general relationship between these characteristics and their influence on conspicuousness is presented in Table 4.1.2-1 and more detailed descriptions of these human-made features are presented below.

Distance-- The impact that individual human-made features have on perception is substantially influenced by the distance from the observer to the feature(s). Viewshed assessments using distance zones or classes often define three classes: foreground, middle ground, and background (Figure 4.1.2-4). For this assessment, we have used the distance classes that have been recently used by the National Park Service:

- Foreground = 0-½ mile from vantage point
- Middle ground = ½-3 miles from vantage point
- Background = 3-60 miles from vantage point. Over time, different agencies have adopted minor variations in the different specific distances use to define these zones, but the overall logic and intent has been consistent.

The foreground is the zone where visitors should be able to distinguish variation in texture and color, such as the relatively subtle variation among vegetation patches, or some level of distinguishing clusters of tree boughs.

Table 4.1.2-1. Characteristics that influence how less conspicuous human-made features are within a viewshed and the general effect.

Characteristic	Less Conspicuous	More Conspicuous
Distance	Distant from the vantage point	Close to the vantage point
Size	Small relative to the landscape	Large relative to the landscape
Color and Shape	Colors and shapes that blend into the landscape	Colors and shapes that contrast with the landscape
Movement and Noise	Lacking movement or noise	Exhibits obvious movement or noise

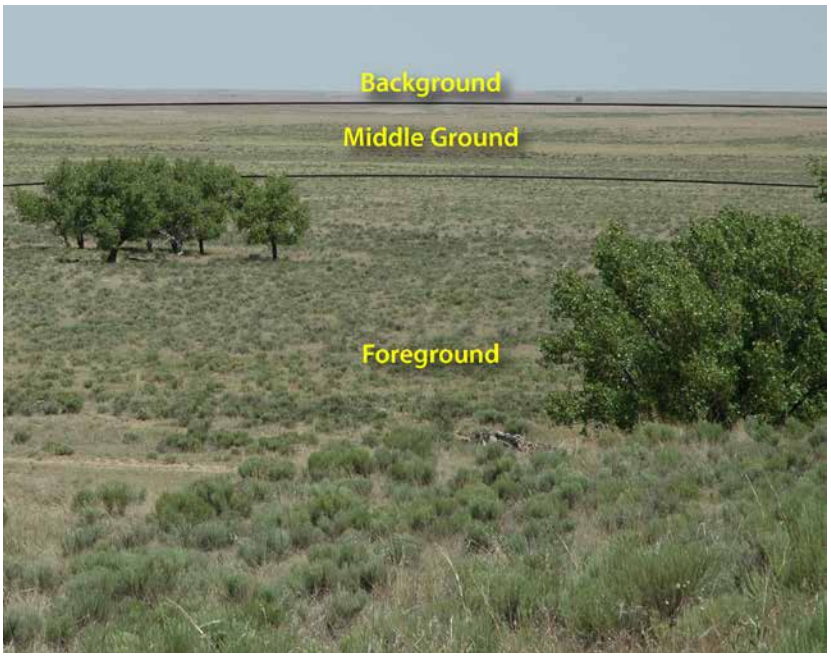


Figure 4.1.2-4. An example of approximate distance classes used in this assessment.

Large birds and mammals would likely be visible throughout this distance class, as would small or medium-sized animals at the closer end of this distance class (USFS 1995). Within the middle ground there is often sufficient texture or color to distinguish individual trees or other large plants (USFS 1995). It is also possible to still distinguish larger patches within major plant community types (such as grasslands), provided there is sufficient difference in color shades at the farther distance. Within the closer portion of this distance class, it still may be possible to see large birds when contrasted against the sky, but other wildlife would be difficult to see without the aid of binoculars or telescopes. The background distance class is where texture tends to disappear and colors flatten. Depending on the actual distance, it is sometimes possible to distinguish among major vegetation types with highly contrasting colors (for example, forest and grassland), but any subtle differences within these broad land cover classes would not be apparent without the use of binoculars or telescopes, and even then may be difficult.

Size

Size is another characteristic that may influence how conspicuous a given feature dominates the landscape, and how it is perceived. For example, Kearney et al. (2008) found human preferences were lower for human-made developments that tended to dominate the view, such as large, multi-storied buildings) and were more favorable toward smaller, single family dwellings. In another study, Brush and Palmer (1979) found that farms tended to be viewed more favorably than views of towns or industrial sites, which ranked very low on visual preference. This is consistent with other studies that have reported rural family dwellings, such as farms or ranches, as quaint and contributing to rural character (Schauman 1979, Sheppard 2001, Ryan 2006), or as symbolizing good stewardship (Sheppard 2001).

We considered the features on the landscape surrounding Sand Creek Massacre NHS as belonging to one of six size classes (Table 4.1.2-2), which reflect the preference groups reported by studies. Using some categories of perhaps mixed measures, we considered size classes within the context of height, volume, and length.

Color and Shape

Studies have shown that how people perceive a human-made feature in a rural scene depends greatly on how well it seems to fit or blend in with the environment (Kearney et al. 2008, Ryan 2006). For example, Kearney et al. (2008) found preferences for homes that exhibit lower contrast with their surroundings as a result of color, screening vegetation, or other

Table 4.1.2-2. A matrix describing the six size classes used for visible human-made features.

	Low Volume	Substantial Volume
Low Height	Single family dwelling (home, ranch house)	Small towns, complexes
Substantial Height	Radio and cell phone towers	Wind farms, oil derecks
Substantial Length	Small roads, wooden power lines, fence lines	Utility corridors, highways

blending factors (see Figure 4.1.2-5). It has been shown that colors lighter in tone or higher in saturation relative to their surroundings have a tendency to attract attention (contrast with their surroundings), whereas darker colors (relative to their surroundings) tend to fade into the background (Ratcliff 1972), O'Conner 2008). This is consistent with the findings of Kearney et al. (2008) who found that darker color was one of the factors contributing to a feature blending in with its environment and therefore preferred. Some research has indicated that color can be used to offset other factors, such as size, that may evoke a more negative perception (O'Conner 2009). Similarly, shapes of features that contrast sharply with their surroundings may also have an influence on how they are perceived. This has been a dominant focus within visual resource programs of land management agencies (Ribe 2005). In forest management, negative perceptions related to the contrasting shapes of forest harvest with their surroundings (for example, clear cuts) was so strong that it was explicitly addressed in the National Forest Management Act of 1976 calling for "cuts shaped and blended to the extent practicable with the natural terrain" (16 USCA 1604g3Fiii). The Visual Resource Management Program of the BLM (BLM 1980) similarly places considerable focus on design techniques that minimize visual conflicts with features such as roads and power lines by aligning them with the natural contours of the landscape. Based on these characteristics of contrast, we considered the color of a feature in relative harmony with the landscape if it closely matched the surrounding environment, or if the color tended to be darker relative to the environment. We considered the shape of a feature in relative harmony with the landscape if it was not in marked contrast to the environment.

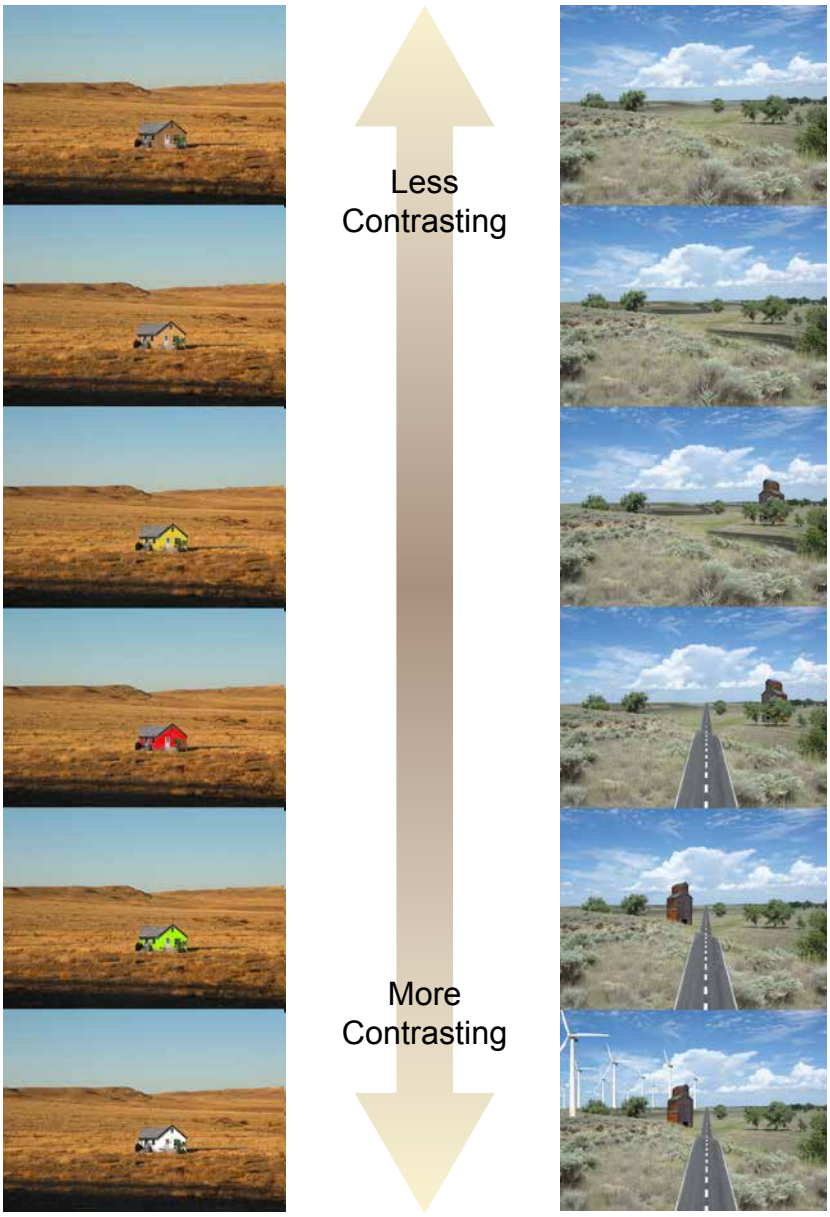


Figure 4.1.2-5. Graphic illustration of how color (left) and shape (right) can influence whether features are in harmony with the environment, or are in contrast.

Movement and Noise

Motion and sound can both have an influence on how a landscape is perceived (Hetherington et al. 1993), particularly by attracting attention to a particular area of a viewshed. Movement and noise parameters can be perceived either positively or negatively, depending on the source and context. For example, the motion of running water generally has a very positive influence on perception of the environment (Carles et al. 1999), whereas noise from vehicles on a highway may be perceived negatively. In Carles et al.'s 1999 study, sounds were perceived negatively when they clashed with aspirations for a given site, such as tranquility. We considered the conspicuousness of the impact of movement and noise to be consistent with the amount present (that is, little movement or noise was inconspicuous, obvious movement or noise was conspicuous).

Hierarchical Relationship among Conspicuousness Measures

The above-described characteristics do not act independently with respect to their influence on the conspicuousness of features; rather, they tend to have a hierarchical effect. For example, the color and shape of a house would not be important to the integrity of the Historic Site's viewshed if the house was located too far away from the vantage point. Thus, distance becomes the primary characteristic that affects the potential conspicuousness. Therefore, we considered potential influences on conspicuousness in the context of a hierarchy based on the distance characteristics having the most impact on the integrity of the viewshed, followed by the size characteristic, then both the color and shape, and movement and noise characteristic (Figure 4.1.2-6).

GIS-based Analyses and Measures

GIS Viewshed Analyses

Viewshed analyses were conducted to depict the total visible area seen from each of the two key vantage points. Aerial maps of each of the vantage points were generated based on digital elevation models (DEMs) to predict the area visible from a given vantage point taking into account changes in elevation and other obstructions such as tree, mountain, or building heights. Ground verification indicated that the initial viewshed analyses tended to underestimate the visible area. Consequently, we adjusted the analyses by experimenting with different offsets that adjust the height of the observer or the surrounding landscape. After several iterations, we found that a 10 m offset for the surrounding landscape provided the best depiction of the visible area from each vantage point. Complete details of the viewshed analysis process are listed in Appendix A.

Indicators/Measures

Housing and Road Densities

Roads and houses are typically the most common noncontributing features within rural landscapes. Thus, we used data provided by NPScape (NPS 2012b) to provide estimates of road and housing densities within the vicinity (approximately 30 km) of the Historic Site. NPScape was developed by the NPS Natural Resource Stewardship and Science Directorate by compiling and analyzing landscape-scale U.S. Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, and others) to resources within natural resource-based parks, resulting in the NPScape database (Budde et al. 2009, Gross et al. 2009).

Use of GIS for Illustrating Spatial Relationships

We also used GIS to show the spatial patterns of the areas visible or not from a given vantage point. This includes prominent features on the landscape that are visible from the primary vantage points at the Historic Site, providing an aerial or "bird's eye" view. These prominent features include roads and structures, as well as other developments that might influence the scenic integrity of the viewshed. We limited this approach to an area of 30 km from Historic Site since features at greater distances have relatively less impact on scenic or historic integrity than those in greater proximity.

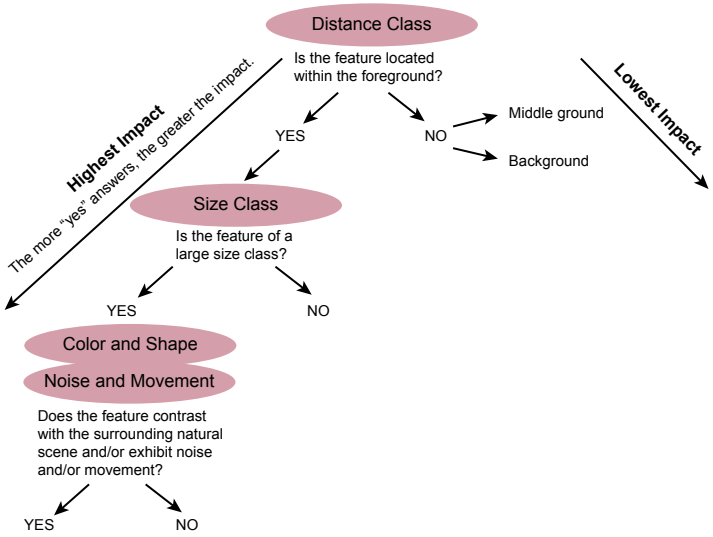


Figure 4.1.2-6. Conceptual framework for hierarchical relationship of characteristics that influence the conspicuousness of features within a viewshed.

Potential Visibility of Wind, Oil & Gas Facilities

Because wind farms are rapidly increasing as well as oil and gas developments,

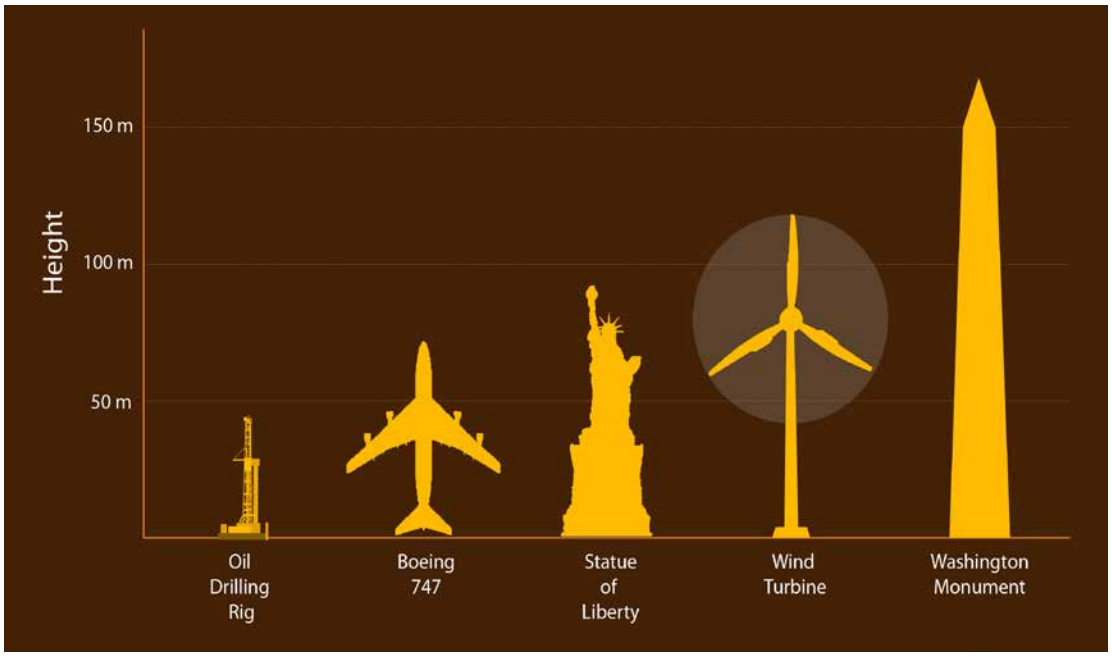


Figure 4.1.2-7. The relative height of oil and gas drilling rigs and wind towers in relation to familiar objects or structures (adapted from U.S. Department of Energy 2013).

we also used the GIS viewshed analysis to estimate the increased visibility of such structures that may stand high on the landscape. The current standard for wind turbine towers is 263ft (80 m), not including the turbine blades, which add an additional 38.5m (U.S. Department of Energy 2013) (Figure 4.1.2-7). Thus, we estimated the area that would be visible if structures were 80 or 118.5 m high. For oil and gas development, the drilling structures, although temporary, would typically be 140 ft (43 m) for for a 1200 horsepower, triple mast rig likely to be used in this area (Pat O'Dell, NPS Petroleum Engineer, pers. comm.). Thus we also estimated the area that would be visible if structures were 43 m high.

4.1.3. Reference Conditions

The indicators and measures of viewshed condition at Sand Creek Massacre NHS are all inter-related and are intended to provide information about how well the views maintain their scenic quality and their ability to evoke a sense of place in an historic context. As previously discussed, the scenic and historic integrity at Sand Creek Massacre NHS overlap considerably. From the historic perspective, the reference state is based on a particular period relevant to the site—in this case, the time of the massacre (1864).

In the case of Sand Creek Massacre NHS, the reference condition is in essence explicitly stated in the enabling legislation. The Historic Site was authorized by Public Law 106-465 on November 7, 2000, which states:

> *MANAGEMENT.—The Secretary shall manage the site— (1) to protect and preserve the site, including— (A) the topographic features that the Secretary determines are important to the site; (B) artifacts and other physical remains of the Sand Creek Massacre; and (C) the cultural landscape of the site, in a manner that preserves, as closely as practicable, the cultural landscape of the site as it appeared at the time of the Sand Creek Massacre;*

Natural landforms and ecological communities also greatly influenced the tactical aspects and outcome of the massacre. These natural features contribute to visitor understanding and appreciation of the site and historical events.

The basis for determining condition in an assessment such as this is a comparison between current condition and some reference. For Sand Creek Massacre NHS we used a qualitative reference state for the scenic and historic integrity of the viewshed (Table 4.1.3-1). Similarly, intactness is intended to

Table 4.1.3-1. Qualitative reference condition classes used for scenic and historic integrity within the viewshed at Sand Creek massacre NHS.

Class	Scenic & Historic Integrity
High Integrity *(Good Condition)*	Some noncontributing features or developments are visible, but the vast majority of the landscape is dominated by natural or historic features. Even if some development has occurred, the scene appears largely intact. The integrity of the historic context is well preserved such that an observer can easily visualize the historic aspect of the viewshed. As such, the features that contribute to the historic integrity are well preserved (even as ruins) and the noncontributing features are non-existent or sufficiently minimal so as to not detract from the historic sense of place.
Moderate Integrity *(Moderate Concern)*	Noncontributing features or developments occupy a moderate portion of the landscape, but sufficient intactness retains much of its integrity. The integrity of the historic context is also largely preserved such that an observer can visualize the historic aspect of the viewshed.
Low Integrity *(Significant Concern)*	The vast majority of the landscape is dominated by noncontributing features or developments, such that little integrity or "sense of place" remains. The integrity of the historic context is essentially lost either from the contributing factors not being well preserved or the noncontributing features overwhelming the potential to visualize the historic aspect of the viewshed.

Table 4.1.3-2. Condition classes that describe intactness of a viewshed.

Condition	Class	Description
Good	Pristine	No man-made structures or developments are visible within the viewshed.
	Minimally Developed	Man-made structures or developments are present, but the vast majority of the landscape is dominated by natural features.
Moderate	Moderately Developed	Man-made structures or developments occupy a moderate portion of the landscape.
Significant Concern	Highly Developed	The vast majority of the landscape is dominated by man-made structures or developments.

convey something about the proportion of the visible landscape that has preserved its naturalness relative to that 1864 landscape. The four qualitative condition classes we used from intactness are presented in Table 4.1.3-2.

Housing and road densities are also intended to provide information about how well the scenic quality and historic sense of place have been preserved, but do so using a GIS-based measure of some specific non-contributing features (houses and roads). However, densities certainly help tell part of the story, but do not provide the full story. For example, two scenes may have equal overall road densities but if one has only rural roads in the distance and the other has a busy interstate highway close to the observation point, the latter will clearly be considered more degraded in terms of their scenic and historic value. Thus we use housing and road densities as a general reference but take into account other factors in a more qualitative sense described in Table 4.1.3-3 .

4.1.4. Condition and Trend

Ground-based Assessment

Overall, the scenic and historic integrity of the viewsheds at Sand Creek Massacre NHS is fairly high and in good condition. The landscape surrounding site remains largely rural and relatively free of non-contributing features.

Assessment from Key Vantage Points

We considered the condition of the view from *Memorial Overlook* to be good (Table 4.1.4-1). From this vantage point, the most prominent non-contributing feature is the Historic Site administrative facility, and even that is relatively inconspicuous due to being shielded by cottonwood trees (Figure 4.1.4-1). The other main non-contributing

Table 4.1.3-3. Condition classes that describe housing and road density.

Condition Class	Description
Good	Undeveloped or rural, agricultural (farm and ranch) housing. Housing densities are primarily < 1.5 units /km^2. Small concentrated areas of higher densities may be found, but usually not in proximity to the observation point and are relatively inconspicuous. Majority of the roads are small, rural roads.
Moderate	Housing densities are more prominent in the landscape (generally between 1.5-6 units per km^2), but the scenic and historic values are largely maintained. A mix of road classes, but predominantly small roads and larger or busy roads are not in the foreground.
Significant Concern	Higher density ex-urban to suburban development (generally densities > 6 units per km^2, such that the scenic and historic value is either lost or close to being lost. Major roads and highways are conspicuous in the view.

feature(s) is the surrounding agricultural and rural development, and little if any of this development is in the foreground, and much of the closest development in the middle ground is relatively inconspicuous. The historic marker is an obvious man-made feature that was not present at the time of the massacre, but especially given the policies of Sand Creek Massacre NHS that allow for offerings to be left, it probably adds, rather than detracts, from the sense of place (Figure 4.1.4-2)

Despite some development, the natural topography and vegetation communities, primarily grasslands and riparian, are dominant influences on the viewshed and contribute positively, largely retaining the sense of place. Most of the non-contributing features the are of relatively low contrast and/or are of sufficient distance to minimize their impact on the viewshed.

The views from the Bluffs Trail Overlook also have high scenic and historic integrity, thus the condition is considered good (Figure 4.1.4-3). Although some rural development is visible, it is neither extensive or conspicuous. The natural vegetation communities, primarily grasslands and riparian, are the dominant influence on the viewshed and contribute well to the sense of place. In terms of area, agriculture is probably the most extensive non-contributing element, at least for the 1864 reference. However, given the distance, angle of view, and color, most of the surrounding agriculture is relatively inconspicuous (Figure 4.1.4-4), with the exception of when recent tillage and/or irrigation result in contrast with the surroundings. But these influences do not tend to be dominant on this landscape.

GIS-based Assessment

We began our GIS-based assessment by modeling the areas visible or not visible from the two key vantage points. At both

Table 4.1.4-1. Summary of primary non-contributing features and viewshed condition assessed at each key vantage point.

Vantage Point	Noncontributing Features	Assessment	Condition
The Memorial Overlook (Figure 4.1.5-1)	Park roads &trails Park Administrative Buildings Agricultural fields & fences Windmills & Grain Silos Rural (ranch) Houses Power Poles	The views from the Memorial Overlook are predominantly of high scenic and historic integrity. The foreground is dominated by natural vegetation with few non-contributing features. What little development has occurred tends to be in the middle ground and background and is relatively inconspicuous.	Good
The Bluffs Trail (Figure 4.1.5-2)	Rural housing Agricultural fields & fences Windmills & Grain Silos Town of Brandon	In terms of condition, the views from the Bluffs Trail Overlook are also predominantly of high scenic and historic integrity. The foreground is dominated by natural vegetation with few non-contributing features. What little development has occurred tends to be in the middle ground and background and is relatively inconspicuous.	Good



Figure 4.1.4-1. Panoramic views in all directions from the Memorial Overlook.

the Memorial Overlook and the Bluffs Trail Overlook, most of the visible area lies to the northwest looking over the massacre site (Figures 4.1.4-5 and 4.1.4-6). Views to the west are limited by the topography, especially from the Bluffs Trail Overlook. The Memorial Overlook also offers more extensive, but still limited, views to the south, which includes route of the calvary approach.

It is important to keep in mind that these estimates of visible area are approximations based on digital elevation models. Although, we have checked them on the ground to verify that they are approximately correct, it should not be assumed that they are exactly correct for the purposes of planning specific projects. Such cases may require further verification, and adjustment if necessary, for the specific context intended.


NPS PHOTO

Figure 4.1.4-2. Although not present at the time of the massacre, the memorial, along with its offerings, probably adds, rather than detracts, from the sense of place by evoking reflection on the events that occurred at this site.

Housing and Road Densities

Based on the data complied in NPScape (Budde et al. 2009 and Gross et al. 2009). housing densities surrounding the Historic Site are relatively low, with > 80% of the square km units being undeveloped (Table 4.1.4-2, Figure 4.1.4-7). Since these data originated from the U.S., Census, units with unknown densities were not likely report; thus likely also undeveloped.

Similarly, road densities are also relatively low (Figure 4.1.4-8), with the majority of the area surrounding the Historic Site having < 3 km of roads per square km, and the highest road densities occurring to the west of the site; thus generally not visible from the site. Roads surrounding the site are also generally restricted to unpaved rural roads with little activity.

The low densities of housing and roads supports the assessment made from vantage

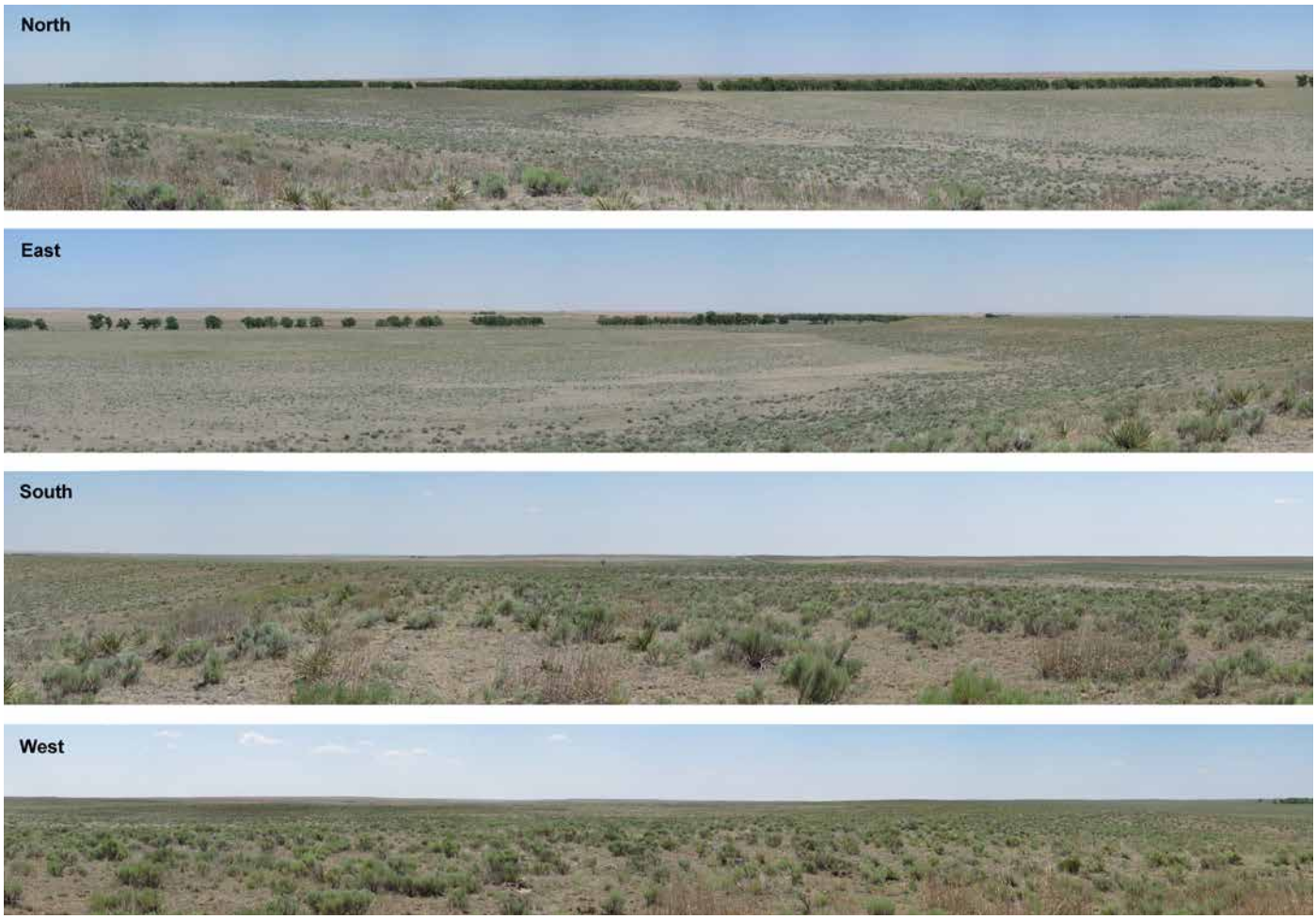


Figure 4.1.4-3. Panoramic views in each direction from the Bluffs Trail Overlook vantage point.

points in that views from the Historic Site tend to be dominated by native vegetation rather than houses or roads. Thus, we do not consider the current densities of housing or roads to be of major concern for the viewshed at the present time.

Visibility of Wind Turbines or Oil and Gas Drilling Rigs

Based on our analyses, the height of non-contributing features such as wind turbines and oil and gas drilling rigs can substantially increase the area from which they are visible. For wind turbines, the height of the tower itself increases the area from which it would be visible by 251% (Table 4.1.3-3) (Figure 4.1.4-9). Taking into account the blades as well as the tower increases the area from which it would be visible by 313%. The effect of oil and gas drilling rigs was considerably less, but still increases the area from which it would be visible by 156% (Figure 4.1.4-10).

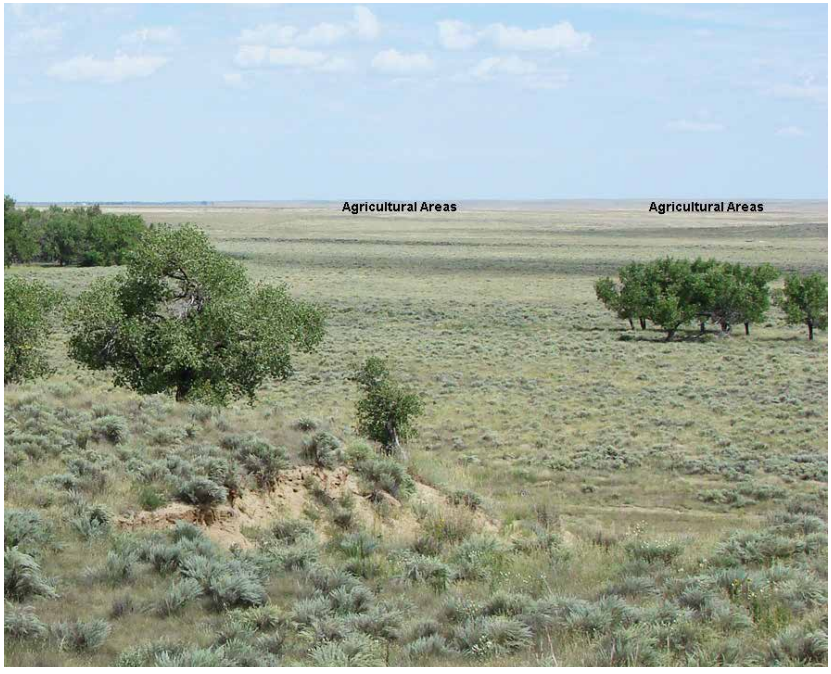


Figure 4.1.4-4. Because of the distance, angle, color, and other factors, the agriculture surrounding Sand Creek Massacre NHS remains relatively inconspicuous from the primary vantage points.

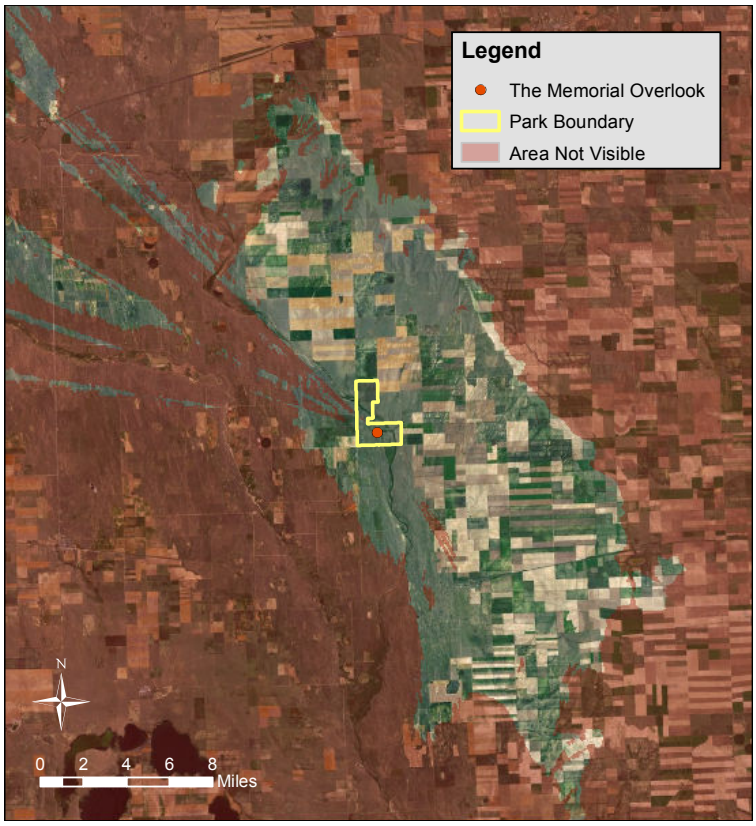


Figure 4.1.4-5. Area visible and not visible from the Memorial Overlook based on GIS analysis.

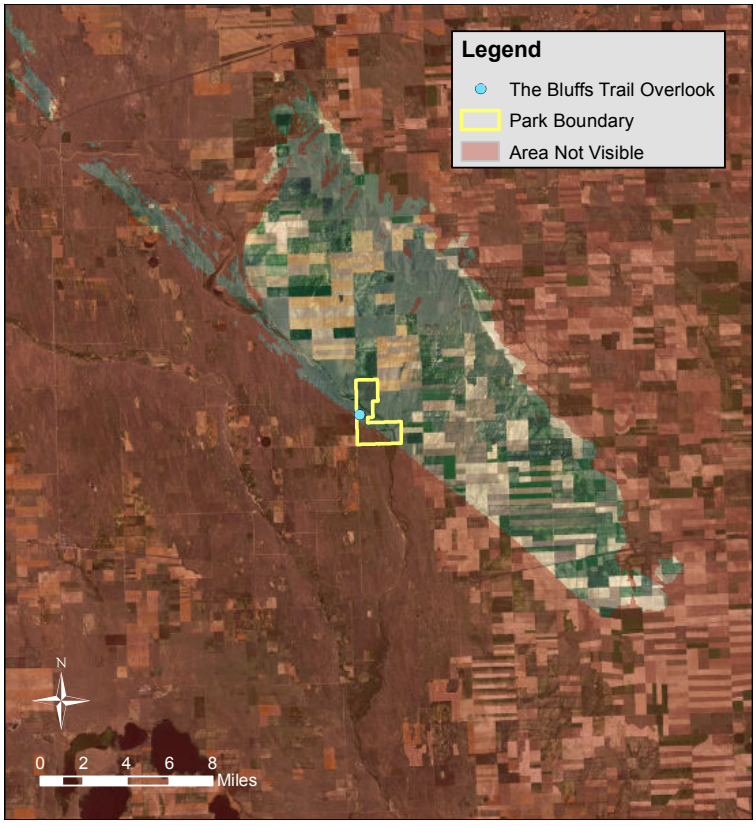


Figure 4.1.4-6. Area visible and not visible from the Bluffs Trail Overlook site based on GIS analysis.

Table 4.1.4-2. Housing and road densities within 30 km of Sand Creek Massacre NHS in 2010 as estimated using NPScape (Budde et al. 2009 and Gross et al. 2009).

Density Class	Area (km²)	Percent
Housing Densities		
Private undeveloped	3103	82.68%
< 1.5 units / square km	333	8.88%
1.5 - 6 units / square km	9	0.25%
> 6 units / square km	7	0.18%
Commercial / Industrial	0.6	0.02%
No Data	300	7.99%
Road Densities		
0.015 - 1.125 km / km²	1431	37.67%
1.126 - 2.287 km / km²	1072	28.22%
2.288 - 4.982 km / km²	158	4.16%
4.983 - 13.49 /km / km²	8	0.21%
> 3.49 /km / km	1	0.03%
No Data	1129	29.72%

Note: The source data from NPScape included some areas with missing data, which were excluded from these totals.

Table 4.1.4-3. The estimated area visible from one or both vantage points and the percentage increase of that area due to height of the feature.

Feature	Visible Area (km²)	% Increase in Visibile Area
Base	874	
Oil & Gas Drilling Rig (43m)	2238	156%
Wind Turbine - Tower only (80m)	3064	251%
Wind Turbine - Tower + blades (118.5m)	3606	313%

Overall Condition

Based on this assessment, the viewshed condition at Sand Creek Massacre NHS is considered good. There has been some development both within and outside the site that can detract from the sense of place, but such development tends to be the middle ground and background of the viewshed and remains relatively inconspicuous. The Historic Site's administrative buildings are well shielded and blend with their surroundings, and the agricultural and rural development

does not dominate the viewshed and is not sufficient so as to detract significantly from the Historic Site's sense of place.

4.1.5. Sources of Expertise

For assessing the condition of this resource, we relied primary on literature on this topic. We did however, use the GIS expertise from Melanie Meyers, GIS Analyst with Colorado State University, while she was working with the Intermountain Region, as well as the values and predictions from the U.S. Census.

Key Uncertainties

How a view is perceived is quite subjective and will always have an element of uncertainty. We have tried to base our assessment on the findings of an extensive body of literature, and have tried to be transparent with our assessment, such that those that disagree can make an argument based on our approach.

Another element of uncertainty is our GIS analysis. This analysis is based on digital elevation models and does not take into account visibility limitations from vegetation, etc. Also, our field verification of our initial analysis indicated that we were underestimating the visible area, which we accounted for using an offset. Further field checks indicated that our final analysis was closer, but undoubtedly still has some error due to the process. Thus, as stated previously, it should not be assumed that our analysis is exactly correct for the purposes of planning specific projects. Such cases may require further verification, and adjustment if necessary, for the specific context intended.

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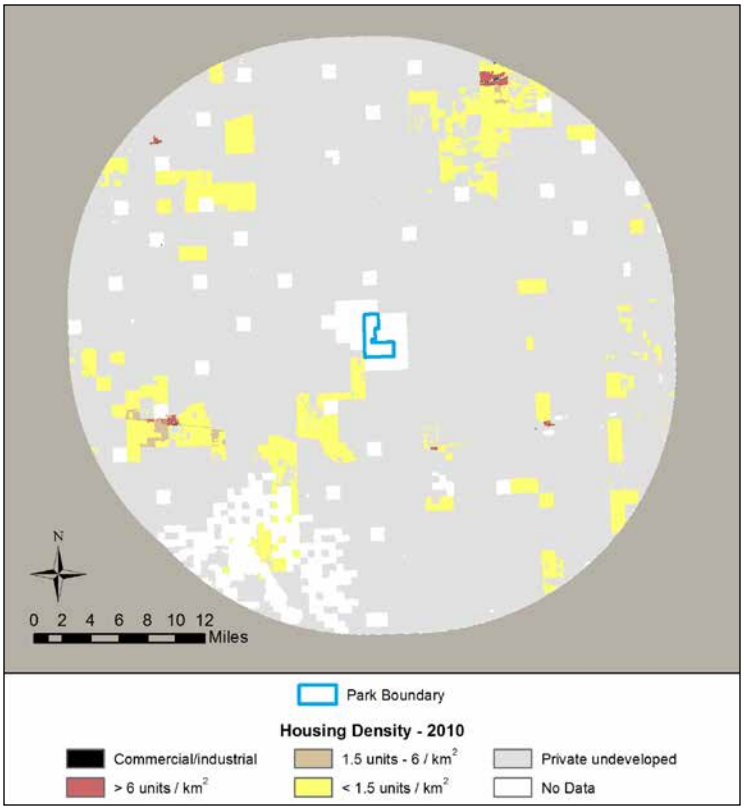


Figure 4.1.4-7. Housing densities (housing units / km2) within 30 km of Sand Creek Massacre NHS based on data compiled in NPScape (Budde et al. 2009 and Gross et al. 2009).

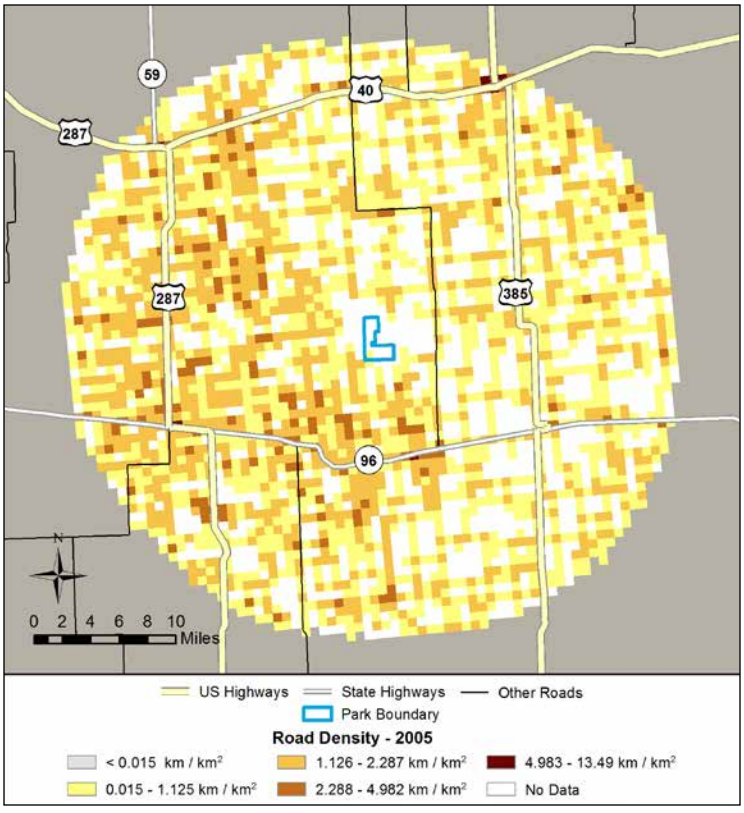


Figure 4.1.4-8. Road densities (km of roads / km2) within 30 km of Sand Creek Massacre NHS based on data compiled in NPScape (Budde et al. 2009 and Gross et al. 2009).

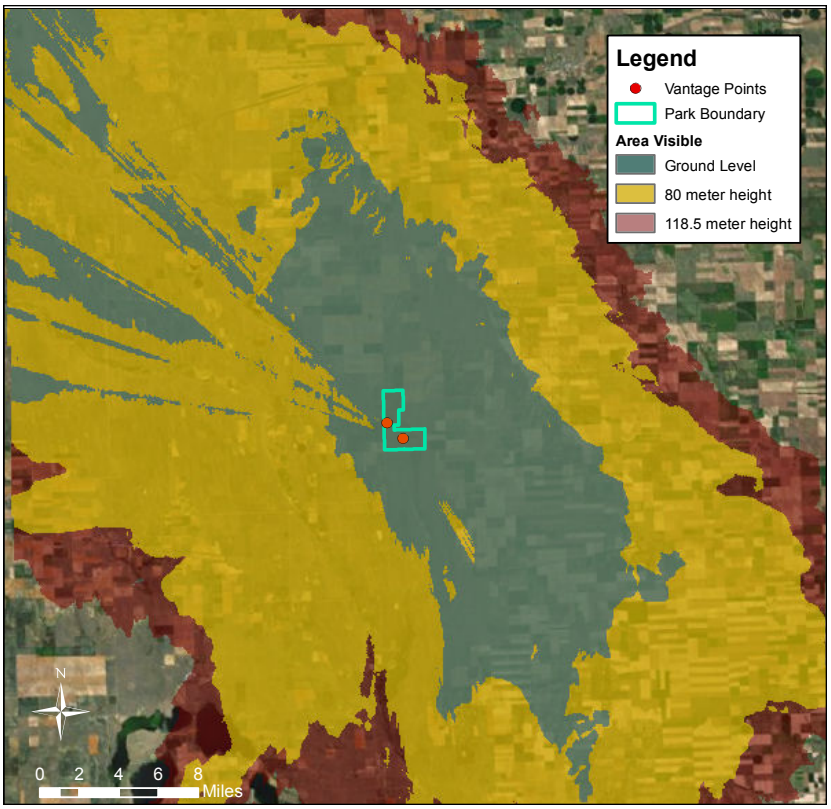


Figure 4.1.4-9. Estimates of the area visible from the Memorial Overlook and/or the Bluffs Trail Overlook. Also shown is the increased area that would be visible for a wind turbine.

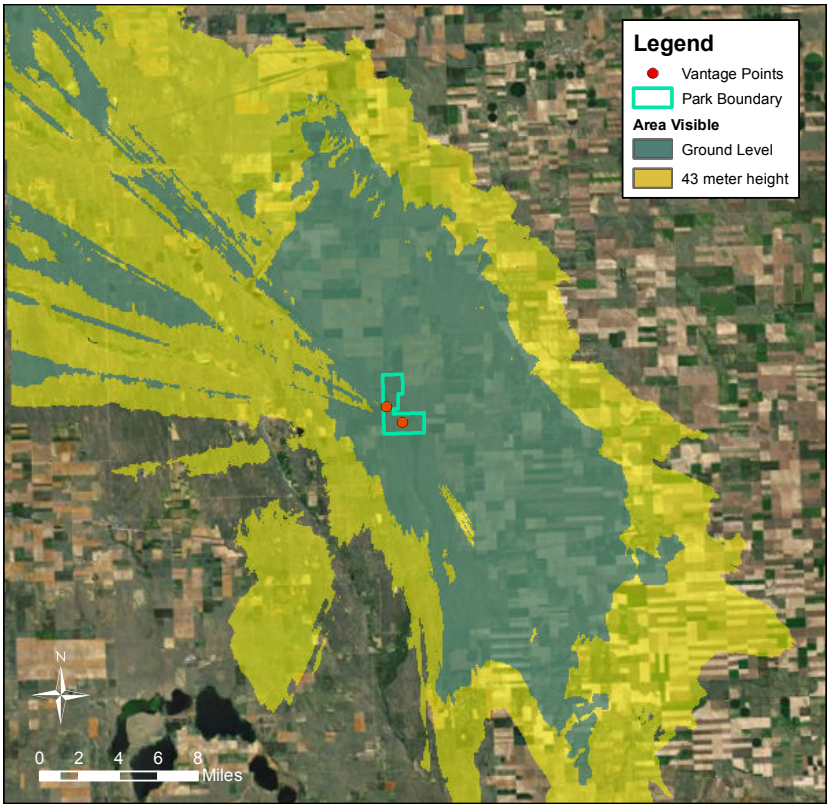


Figure 4.1.4-10. Estimates of the area visible from the Memorial Overlook and/or the Bluffs Trail Overlook. Also shown is the increased area that would be visible for an oil & gas drilling rig.

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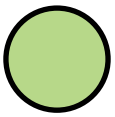
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4.2. Night Sky

Indicators/Measures

- Anthropogenic Light Ratio
- ZenithSky Brightness
- Limiting Magnitude
- Bortle Dark-Sky Scale

Condition – Trend - Confidence



Good – Insufficient Data – High

4.2.1. Background and Importance

Natural dark skies are a valued resource within the NPS, and NPS Management Policies (NPS 2006) highlight the importannce of a natural photic environment to ecosystem function, and the importance of the natural lightscape for aesthetics. The NPS Natural Sounds and Night Skies Division makes a distinction between a *lightscape*—which is the human perception of the nighttime scene, including both the night sky and the faintly illuminated terrain, and the *photoic environment*—which is the totality of the pattern of light at night at all wavelengths (Moore et al. 2013).

Lightscapes are an aesthetic and experiential quality that are integral to natural and cultural resources (Moore et al. 2013). A 2007 visitor survey conducted throughout Utah national parks found that 86% of visitors thought the quality of park night skies was "somewhat important" or "very important" to their visit. Additionally, in an estimated 20 national parks, stargazing events are the most popular ranger-led program (NPS 2010).

The values of night skies goes far beyond visitor experience and scenery. The photic environment affects a broad range of species, is integral to ecosystems, and is a natural physical process (Moore et al. 2013). Natural light intensity varies during the day-night (diurnal) cycle, the lunar cycle, and the seasonal cycle. Organisms have evolved to respond to these periodic changes in light levels in ways that control or modulate movement, feeding, mating, emergence, seasonal breeding, migration, hibernation, and dormancy. Plants also respond to light levels by flowering, vegetative growth, and even their direction of growth (Royal Commission on Environmental Pollution 2009). Given the effects of light on living organisms, it is likely that the introduction of artificial light into the natural light/darkness regime will disturb the normal routines of many plants and animals (Royal Commission on Environmental Pollution 2009), as well as diminish stargazing recreational opportunities offered to national park visitors.

Sand Creek Massacre National Historic Site (NHS) is primarily a cultural resource park, and the cultural significance of dark night skies should be recognized in that context as part of the cultural landscape. The Historic Site is a memorial to the 1864 massacre of Cheyenne and Arapaho people. The Plains Tribes were nomadic and closely followed the seasons, the movement of the sun, and the night sky. Much of their culture was shaped by celestial observation. It is said that Col. John Chivington led 675 men toward Sand Creek on November 28 and navigated by the North Star. This would have been an opportune time to travel because there would have been a full moon (as estimated by NASA 2012). It would have given the cavalry some light to travel by at night.

For the Plains Tribes, winter was the time of the year for storytelling, as families gathered together in the evenings. One Cheyenne story called The Quillwork Girl and her Seven Brothers is about a girl and her brothers who escape a monster buffalo to live in the sky, and become the constellation Pleiades (McHenry 2012). Stories about constellations are often about families or siblings who stay together in the sky (Moroney 2011). Below is another story about the origin of stars that seems relevant to the Arkansas River and Big Sandy Creek and the windy plains of southern Colorado where the Historic Site is located (McHenry 2012):

> The Arapaho and the Cheyenne believed that everything came from the earth, even the stars in the sky. They would travel around underneath the ground until they found the roots of the magical cottonwood tree. They would climb up inside the tree's roots, into the trunk, and out into the branches where they would hide.
>
> One night, the spirit of the night sky looked around and thought, "I don't have enough stars. I want more stars!" So the spirit of the night sky called down to the spirit of the wind and asked for more stars. The spirit of the wind knew that the stars were hiding in the branches of the cottonwood tree, so the spirit of the wind started to blow, and blew harder and harder until the wind blew so hard that the branches of the cottonwood tree broke off right where the stars were hiding. The stars came flying out and up into the night sky.
>
> This is how the Arapaho and Cheyenne believed stars got into the night sky. Find a stick under the cottonwood tree and break it right where the rings are. Look inside to find a five point star shadow right where the stars were hiding!

In addition, an interview of Robert Toahty, a member of the Kiowa/Arapaho of Colony, Oklahoma, by Roberts and Sandlin (1999) lends insight into the feeling surrounding the site of the massacre as follows:

> Q: Where you felt the presence the strongest, or where you really felt the massacre had taken place, are they any landmarks at all?
>
> A: No, there were no landmarks. Just a feeling. There are little rises in the ground. When I close my eyes while walking, it's like a light that's on the top of the earth that's illuminating, but you can't see it. You can feel it but you can't see it. I don't know how to explain it. When you close your eyes, it's not a black background. It's an illuminated background, like a little rise over the earth, like it has a halo or a little dome over it. Sometimes I can't explain it. There's just people there that should have gone on. Sometimes it's horses, or wagon trains, donkeys, not just people [in other places].

Protecting the night sky resources at Sand Creek Massacre NHS benefits the natural resources, is important for visitor experience, and has cultural and historical significance.

4.2.2. Data and Methods

The NPS Night Skies Program conducted an assessment using both qualitative methods used by amateur astronomers to evaluate the potential quality for star gazing and quantitative measures of night sky brightness derived from charged coupled device (CCD) camera images and night sky quality readings. The program's goals of measuring night sky brightness are to describe the quality of the lightscape, quantify how much it deviates from natural conditions, and how it changes with time due to changes in natural conditions, as well as artificial lighting in areas within and outside of the national parks (Duriscoe et al. 2007).

Based on new guidance (Moore et al. 2013), the NPS Natural Sounds and Night Skies Division recommends that the all-sky Anthropogenic Light Ratio (ALR) is the best single parameter for characterizing the overall sky condition. Additional indicators and measures may be considered in an assessment of night sky condition, but the ALR measure is the primary data source for condition assessment.

Indicators/Measures

Anthropogenic Light Ratio

The anthropogenic light ratio (ALR) is the average anthropogenic sky luminance presented as a ratio over natural conditions. It is a useful metric to average the light flux over the entire sky (measuring all that is above the horizon and omitting the terrain). Recent advances in modeling of the natural components of the night sky allow the

separation of anthropogenic light from natural features, such as the Milky Way. This metric is a convenient and robust measure. It is most accurately obtained from ground-based measurements with the NPS Night Skies Program's photometric system, however, it can also be modeled with moderate confidence when such measurements are not available.

CCD camera images assess brightness, including maximum sky brightness, minimum sky brightness, and two measures of integrated sky brightness. The maximum sky brightness is typically found in the core of urban light domes (i.e., the semicircular-shaped light along the horizon caused by the scattering of urban light). The minimum sky brightness is typically found at or near the zenith (i.e., straight overhead). The integrated night sky brightness is calculated from both the entire celestial hemisphere as well as a measure of the integrated brightness masked below 20o altitude to avoid site-to-site variations introduced by terrain and vegetation blocking.

Indicators/Measures

Zenith Sky Brightness

Sky brightness describes the amount of light in the night sky. One method of assessing sky brightness uses a Unihedron Sky Quality Meter (SQM) that samples the night sky in a broad spectrum band roughly corresponding to the entire human visual range. The SQM measures an aggregate average brightness for the entire sky that is skewed to zenith brightness (Moore 2012). Two readings were taken at Sand Creek Massacre NHS.

Indicators/Measures

Limiting Magnitude

Limiting magnitude (LM) is a semi-quantitative measurement of the brightness of the faintest stars visible to the naked eye (Bortle 2001, Moore 2001). It is also a measure commonly used by amateur astronomers to judge the quality of the night sky because it is simple to measure and requires no special equipment (Bortle 2001). Estimates are made using star counts of 25 sample areas, each with known brightness values (Moore 2001).

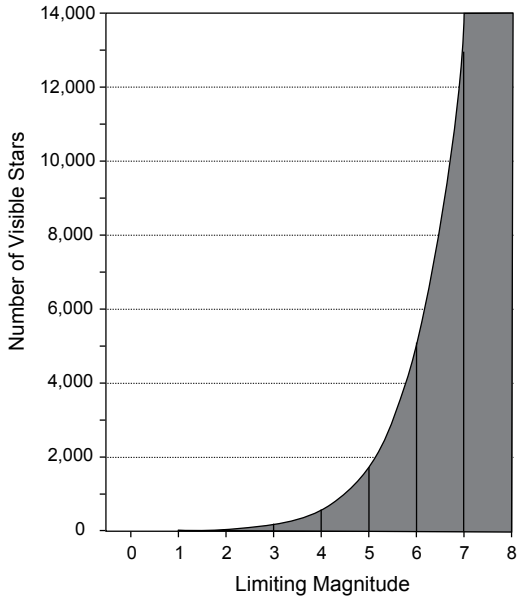


Figure 4.2.2-1. There is a sharp drop-off in number of visible stars as light pollution increases and the limiting magnitude decreases (adapted from Moore 2001).

In addition to its wide use and simplicity, LM can be expressed in ways that are intuitively easy to understand. For example, increases in night sky brightness (e.g., from light pollution) reduces the contrast between stars and their background, thus reducing an observer's ability to see fainter stars (Moore 2001). Moore (2001) further expressed this graphically by showing the relationship between LM and the number of stars that are visible to the naked eye (Figure 4.2.2-1); the LM scale is located in Table 4.2.2-1 along with the Bortle Dark Sky Scale. One drawback to using limiting magnitude as an indicator is that it does not perform well at the brighter and darker extremes compared to the Bortle Dark Sky Scale (Moore 2001). Another drawback of LM is that observer bias can skew results and the method is sensitive to atmospheric haze; however, it still provides a relatively easy measurement that can be used in conjunction with other night sky condition measurements.

Indicators/Measures

Bortle Dark Sky Scale

The Bortle Dark Sky Scale (Appendix C) was proposed by John Bortle (Bortle 2001) based on 50 years of astronomical observations. Bortle's qualitative approach uses a nine-class scale that requires a basic knowledge of the night sky and no special equipment. (Bortle 2001, Moore 2001, White et al. 2012, Table 4.2.2-1). The Bortle scale uses both

Table 4.2.2-1. Bortle Dark Sky Scale*

Bortle Scale	LM	Milky Way (MW)	Astronomical Objects	Zodiacal Constellations	Airglow and Clouds	Nighttime Scene
Class 1 Excellent Dark Sky Site	7.6-8.07	MW shows great detail, and appears 40° wide in some parts; Scorpio-Sagittarius region casts an obvious shadow	Spiral galaxies (M33 and M81) are obvious objects; the Helix nebula is visible with the naked eye	Zodiacal light is striking as a complete band, and can stretch across entire sky	The horizon is completely free of light domes, very low airglow	Jupiter and Venus annoy night vision, ground objects are barely lit, trees and hills are dark
Class 2 Typical Dark Site	7.1-7.5	MW shows great detail and cast barely visible shadows	The rift in Cygnus star cloud is visible; the Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares	Zodiacal band and gegenschein are visible	Very few light domes are visible, with none above 5° and fainter than the MW; airglow may be weakly apparent, and clouds still appear as dark voids	Ground is mostly dark, but object projecting into the sky are discernible
Class 3 Rural Sky	6.8-7.0	MW still appears complex; dark voids and bright patches and a meandering outline are visible	Brightest globular clusters are distinct, pinwheel galaxy visible with averted vision	Zodiacal light is easily seen, but band of gegenschein is difficult to see or absent	Airglow is not visible, and clouds are faintly illuminated except at zenith	Some light domes evident along horizon, ground objects are vaguely apparent
Class 4 Rural-Suburban Transition	6.3-6.7	MW is evident from horizon to horizon, but fine details are lost	Pinwheel galaxy is a difficult object to see; deep sky objects such as M13 globular cluster, Northern Coalsack dark nebula, and Andromeda galaxy are visible	Zodiacal light is evident, but extends less than 45° after dusk	Clouds are just brighter than the sky, but appear dark at zenith	Light domes are evident in several directions (up to 15° above the horizon), sky is noticeably brighter than terrain
Class 5 Suburban Sky	5.6-6.2	MW is faintly present, but may have gaps	The oval of Andromeda galaxy is detectable, as is the glow in the Orion nebula, Great rift in Cygnus	Only hints of zodiacal light may be glimpsed	Clouds are noticeably brighter than sky	Light domes are obvious to casual observers, ground objects are easily seen
Class 6 Bright Suburban Sky	5.1-5.5	MW only apparent overhead, and appears broken as fainter parts are lost to sky glow	Cygnus, Scutum, and Sagittarius star fields just visible	Zodiacal light is not visible; constellations are seen, and not lost against a starry sky	Clouds appear illuminated and reflect light	Sky from horizon to 35° glows with grayish color, ground is well lit
Class 7 Suburban-Urban Transition	4.6-5.0	MW may be just barely seen near the zenith	Andromeda galaxy (M31) and Beehive cluster (M44) are rarely glimpsed	Zodiacal light is not visible, and brighter constellations are easily seen	Clouds are brilliantly lit	Entire sky background appears washed out, with a grayish or yellowish color
Class 8 City Sky	4.0-4.5	MW not visible	Pleiades are easily seen, but few other objects are visible	Zodiacal light not visible, constellations are visible but lack key stars	Clouds are brilliantly lit	Entire sky background has uniform washed out glow, with light domes reaching 60° above the horizon
Class 9 Inner City Sky	<4.0	MW not visible	Only the Pleiades are visible to all but the most experienced observers	Only the brightest constellations are discernible	Clouds are brilliantly lit	Entire sky background has a bright glow, ground is illuminated

*Table 4.2.2-1 also incorporates the Bortle Dark Sky Scale Key for the Summer Sky for Latitudes 30° to 50° N, White et al. 2012.

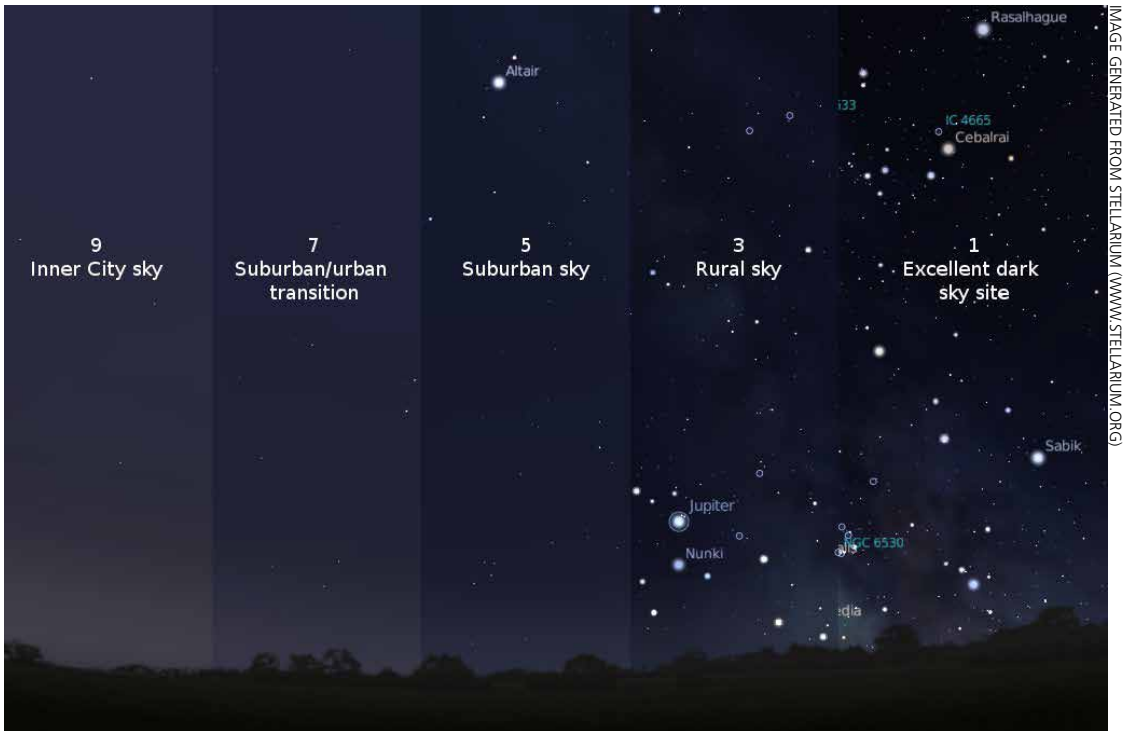


Figure 4.2.2-2. Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.

stellar objects and familiar descriptors to distinguish among the different classes. Another advantage of the Bortle scale is that it is suitable for conditions ranging from the darkest skies to the brightest urban areas (Moore 2001, Figure 4.2.2-2).

4.2.3. Reference Conditions

The ideal night sky reference condition, regardless of how it's measured, is one devoid of any light pollution. However, results from night sky data collection throughout more than 90 national parks suggest that a pristine night sky is very rare (NPS 2010). A natural night sky has an average brightness across the entire sky of 80 nL (nanolamberts, a measure of luminance), or 21.60 magnitudes per square arc second (Duriscoe 2013 [submitted]) and includes features such as the Milky Way, Zodiacal light, airglow, and other starlight. This is figured into the ratio, so that an ALR reading of 0.0 would indicate pristine natural conditions where the anthropogenic component was 0 nL. A ratio of 1.0 would indicate that anthropogenic light was 100% brighter than the natural light from the night sky. For a summary of condition assessment categories for all night sky indicators, see Table 4.2.3-1.

Anthropogenic Light Ratio

The threshold for night skies in good condition is an ALR <0.33 and the threshold for a moderate condition is ALR 0.33-2.0. An ALR >2.0 suggests significant concern (Moore et al. 2013).

Zenith Sky Brightness

Reference conditions for night sky brightness can vary moderately based on the time of

Table 4.2.3-1. Night sky condition class summary.

Condition Class	ALR*	SQM	Limiting Magnitude	Bortle Scale
Good	ALR <0.33 (<26 nL average anthropogenic light in sky)	≥21.60	≥6.8	1-3
Moderate	0.33-2.0 (26-156 nL average anthropogenic light in sky)	21.2-21.59	6.3-6.7	4
Significant concern	ALR >2.0 (>156 nL average anthropogenic light in sky)	<21.2	≤6.2	5-9

*at least half of the park's geographic area should meet the standard described

night (time after sunset), time of the month (phase of the moon), time of the year (the position of the Milky Way), and the activity of the sun which can increase "airglow"—a kind of faint aurora. For the *minimum* night sky brightness measure, the darkest part of a natural night sky is generally found near the zenith. A value of 22.0 magnitudes per square arc second (msa) is considered to represent a pristine sky, though it may vary naturally by more than +0.2 to -0.5 depending on natural conditions (Duriscoe 2013 [submitted]). Lower (brighter) values indicate increased light pollution and a departure from natural conditions. The astronomical magnitude scale is logarithmic, so a change of 2.50 magnitudes corresponds to a difference of l0x (100%); thus a 19.5 msa sky would be 10x brighter than natural conditions.

The *maximum* night sky brightness is often found within the Milky Way of a natural sky. A typical measurement from the Sagittarius region of the Milky Way in a natural sky yields 19.2 msa. Other regions of the Milky Way are somewhat dimmer, or around 20.0-21.0 msa. A value brighter than 19.0 msa will result in impairment to human night vision and may be noticeable by casting faint shadows or causing glare. A value lower (brighter) than 17.0 represents very bright areas of the night sky and would significantly impair human night vision and cast obvious shadows. Values for the brightest portion of the sky are of interest to the NPS because they represent unnatural intrusions on the nightscape, will prevent human dark-adapt vision, and may have effects on wildlife (Duriscoe et al. 2007). Under a natural sky, the maximum brightness observed is typically 21.0 to 21.5 msa, exclusive of the Milky Way (Moore 2012).

Bortle Dark Sky Scale and Limiting Magnitude

A night sky with a Bortle Dark Sky Scale class 1 (LM>7.6) is considered in the best possible condition (Bortle 2001); unfortunately, a sky that dark is so rare that few observers have ever witnessed it (Moore 2001). Non-urban park skies with a Bortle class 3 or darker (LM $\geq$6.8) are considered to be in good condition, class 4 (LM 6.3-6.7) of moderate condition, and class 5 (LM<6.2) are considered poor condition. At class 4 and higher, many night-sky features are obscured from view due to artificial lights (either within or outside the park). Skies class 7 and higher have a significantly degraded aesthetic quality that may introduce ecological disruption (Moore et al. 2013). It is important to note that such degraded conditions may be restored toward a more natural state by modifying outdoor lighting, depending on the surrounding conditions that exist outside the park.

4.2.4. Condition and Trend

Data were collected in January 2010 by the NPS Night Skies Program and show an ALR of 0.2 (based on ground-based measurement, not modeling), indicating good condition.

A supplementary, rapid assessment was conducted at Sand Creek Massacre NHS on January 13, 2010 consisting of SQM readings and Bortle class and limiting magnitude estimates. Two SQM readings were taken and the middle values were 21.79 and 21.75 msa, which indicate good condition. The Bortle Scale assessment was rated a 3 (see Table 4.2.4-1).

Local and Regional Context

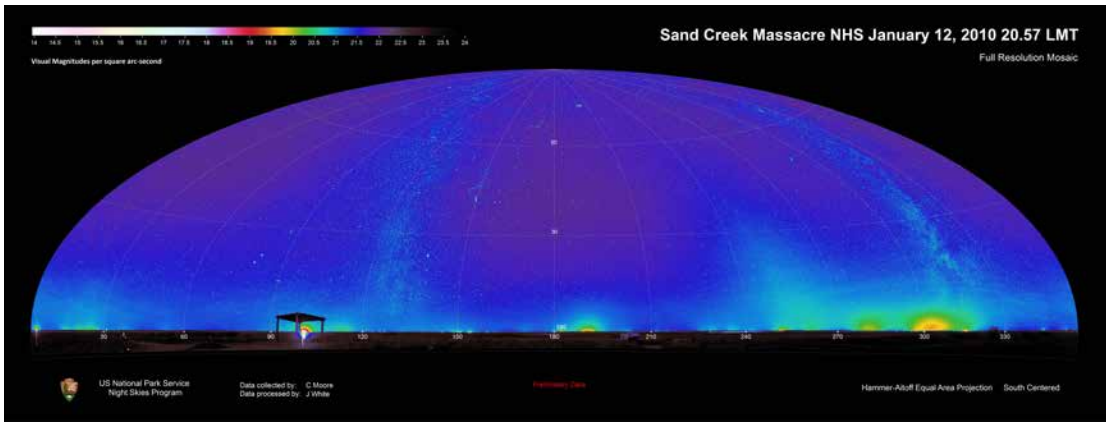
Sand Creek Massacre NHS is located in rural southeast Colorado in Kiowa County, the fifth least densely populated of the 64 counties of the State of Colorado with a county population of approximately 1,398 people (U.S. Census Bureau 2013a; Figure 4.2.4-1). According to U.S. Census information, the population of the county has been declining since the 1960s (U.S. Census Bureau 2013b). Denver and other cities are visible a from the Historic Site, however, at distances of 100 to 250 kilometers; and their population trend has been upwards. Future threats may be more likely to come from regional cities than local sources. The Historic Site is relatively small, and some roads and farm buildings are visible from the Historic Site and can influence the night sky.

Overall Condition

For assessing the condition of the night sky, several qualitative indicators (Bortle Dark Sky Scale, limiting magnitude) and quantitative measures (sky brightness, anthropogenic

Table 4.2.4-1. Summary of night sky indicators and measures, and assessment of night sky condition at Sand Creek Massacre National Historic Site.

Indicator	Measure	Interpretation	Condition
Anthropogenic Light Ratio	0.2	Sum of Anthropogenic sources are only 20% as bright as the aggregate light from the entire sky.	Good
Zenith Sky Brightness	21.79 21.75	Zenith Sky Brightness measures indicate very low degree of anthropogenic light detectable at the zenith	Good
Limiting Magnitude	7.0	A single light from a nearby farm impacted dark adaptation	Good
Bortle Scale Class	3	Moderately bright airglow and artificial sources are obvious in most directions, though they effect a moderately small fraction of the sky	Good



light ratio) were used. These indicators are summarized and interpreted in Table 4.2.4-2. The overall condition of the Historic Site's night sky is good and there is excellent agreement among the four parameters.

Uncertainties

The Bortle Dark Sky Scale and sky brightness estimates have inherent uncertainties and error. The principle drawback of the Bortle Scale and LM is that both rely on human visual observers. Differences in visual acuity, experience and knowledge, as well as time and effort expended can influence the estimates (Bortle 2001, Moore 2001). The sky brightness measures taken with the SQM suffers similar operator bias based on the level of experience in using the SQM and assessing the surrounding conditions. These readings should be interpreted as interim until the CCD camera

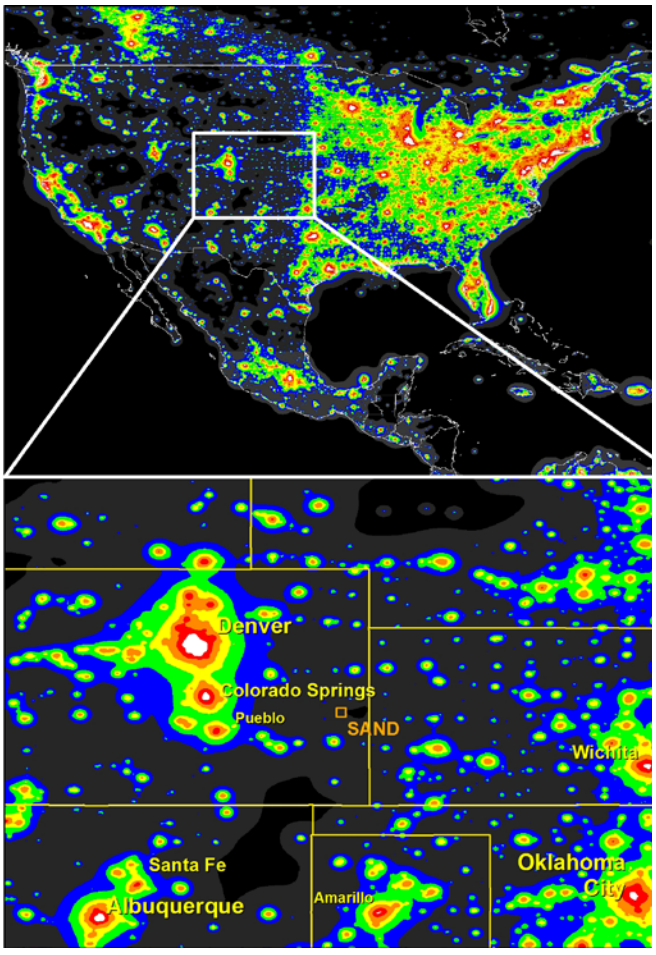


Figure 4.2.4-1. Night sky image of Sand Creek NHS taken by the NPS Night Skies Program (above); and artificial brightness in North America and the relative location of Sand Creek Massacre NHS (below, Cinzano et al. 2001).

Table 4.2.4-2. Summary of the night sky indicators and their contributions to the overall night sky natural resource condition assessment.

Indicator	Description of How the Indicator Contributes to the Overall Resource Condition	General Contribution of this Indicator to the Overall Resource Condition
Anthropogenic Light Ratio	Anthropogenic light ratio (ALR) is a quantitative measure that presents the ratio of the average anthropogenic sky luminance to the average natural sky luminance.	The NPS Night Sky Program collected all-sky ALR data in January 2010 with a value of 0.20, indicating good condition.
Zenith Sky Brightness	This is a quantitative measure that assesses the sky brightness using readings from a sky quality meter (SQM).	SQM readings were taken as part of a supplemental, rapid assessment. The readings indicated a good condition rating.
Limiting Magnitude	This is also a semi-quanititative measure that local astronomers use to assess the brightness of the faintest stars to the naked eye. The limiting magnitude scale closely follows the Bortle Dark Sky Scale.	The limiting magnitude yielded a value of 7.0, which is consistent with the value assigned using the Bortle scale, suggesting a rural sky in good condition.
Bortle Dark Sky Scale	This is a qualitative measure that uses a scale divided into nine classes. It is a relatively easy measure to use for night sky conditions and requires no special equipment. The scale is based on observing features of the night sky including the Milky Way, constellations, and the nighttime scene.	The Historic Site's night sky was assessed to be typical of rural sky. This is considered good condition.

system and measurement of night sky brightness can be analyzed and interpreted. While the CCD system is highly precise, it can also be affected by vagaries in the atmosphere and in fluctuations in natural night sky brightness. Research is underway to minimize the influences of these factors upon the quantification of artificial light; and existing data can eventually be post-processed to this new standard (C. Moore, NPS, pers. comm.).

4.2.5. Sources of Expertise

Chad Moore, Chad Moore, Natural Sounds and Night Skies Division, part of the NPS Natural Resource Stewardship & Science Directorate provided information pertaining to night sky data collection methodology and interpretation of results. Moore earned a master's degree in earth science in 1996 and began working for the NPS shortly thereafter. Moore is the Night Skies Program manager, a small team of scientists that measure, restore, and promote the proper management of the night sky resource. He and team member, Dan Duriscoe have developed an automated all-sky camera capable of precise measurement of light pollution. Since 2001 the team has collected sky quality inventories at over 110 U.S. national parks.

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4.3. Soundscape

Indicators/Measures

- Amount of acoustical environment comprised of natural sound vs. anthropogenic noise
- Are types of sounds consistent with designated park uses?
- Characteristics of anthropogenic noise

Condition – Trend - Confidence



Good – Insufficient Data - High

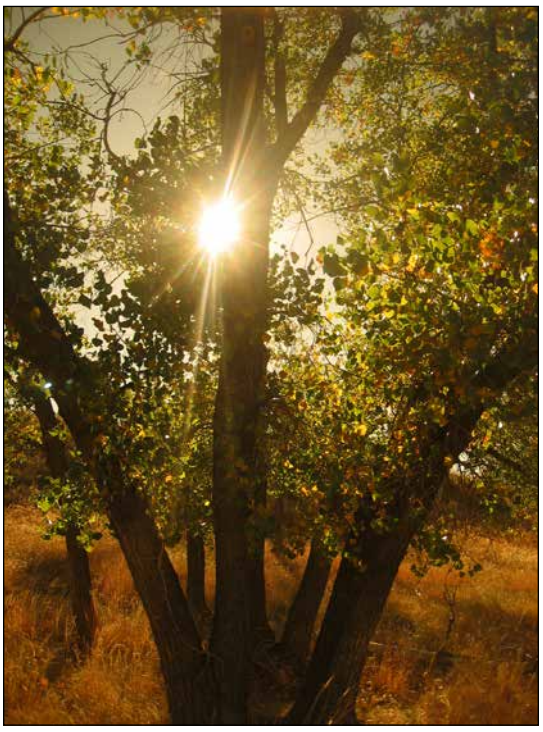
4.3.1. Background and Importance

Our ability to see is a powerful tool for experiencing our world, but sound adds a richness that sight alone cannot provide. In many cases, hearing is the only option for experiencing certain aspects of our environment, and an unimpaired acoustical environment is an important part of overall NPS visitor experience and enjoyment as well as vitally important to overall ecosystem health.

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet that parks can offer. In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors "consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks" (Figure 4.3.1-1) (McDonald et al. 1995). Despite this desire for quiet environments, anthropogenic noise continues to intrude upon natural areas and has become a source of concern in national parks (Lynch et al. 2011).

Sound also plays a critical role in intraspecies communication, courtship and mating, predation and predator avoidance, and effective use of habitat. Studies have shown that wildlife can be adversely affected by sounds that intrude on their habitats. While the severity of the impacts varies depending on the species being studied and other conditions, research strongly supports the fact that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances. Documented responses of wildlife to noise include increased heart rate, startle responses, flight, disruption of behavior, and separation of mothers and young (Selye 1956, Clough 1982, USDA 1992, Anderssen et al. 1993, NPS 1994,).

A park's natural soundscape is an inherent component of "the scenery and the natural and historic objects and the wildlife" protected by the Organic Act of 1916. NPS Management Policies (§ 4.9) (2006a) require the NPS to preserve parks' natural soundscapes and restore degraded soundscapes to natural conditions wherever possible. Additionally, NPS is required to prevent or minimize degradation of the natural soundscapes from noise (i.e., inappropriate/undesirable human-caused sound). Although the management policies currently refer to the term soundscape



MARK SIMMONS

Figure 4.3.1-1. Sounds of nature, are an important aspect of the visitor experience at national parks.

as the aggregate of all natural sounds that occur in a park, NPS' Natural Sounds and Night Skies Division (NSNSD) aims to update this terminology. Because the NPS works to protect and enhance park resources and visitor experiences, NSNSD differentiates between the physical sound sources and human perceptions of those sounds. Currently, NSNSD refers to the physical sound resources (i.e., wildlife, waterfalls, wind, rain, and cultural or historical sounds), regardless of their audibility, at a particular location, as the acoustical environment, while the human perception of that acoustical environment is defined as the soundscape. Clarifying this distinction will allow managers to create objectives for safeguarding both the acoustical environment and the visitor experience.

Sand Creek Massacre NHS was established to recognize the importance of the Sand Creek Massacre as a nationally significant element of frontier military and Native American history, and to serve as a symbol of the struggles of Native American tribes to maintain their way of life on ancestral land (SAND Public Law 106– 465 2000).

The massacre occurred in a remote, unpopulated region of southeastern Colorado, and the site is virtually as isolated and sparsely populated today as it was in 1864 when the massacre occurred. A monument has been placed in the park to commemorate the ambushed victims and offers a designated area for victims' families and park visitors to have a physical connection with the massacre site's natural setting and to experience uninterrupted solitude and contemplation (NPS 2006b) (Figure 4.3.1-2). In general, the types and characteristics of sound greatly affects a park visitor's ability to experience solitude, and unfortunately, areas providing a quiet acoustical environment are becoming increasingly rare.

4.3.2. Data and Methods

What is Sound? (Sound Science 101)

Humans and wildlife perceive sound as an auditory sensation created by pressure variations that move through a medium such as water or air. Sound is measured in terms of frequency (pitch) and amplitude (loudness) (Templeton and Sacre 1997, Harris 1998).

Frequency, measured in Hertz (Hz), describes the cycles per second of a sound wave, and is perceived by the ear as pitch. Humans with normal hearing can hear sounds between 20 Hz and 20,000 Hz, and are most sensitive to frequencies between 1,000 Hz and 6,000 Hz. High frequency sounds are more readily



Figure 4.3.1-2. Sand Creek Massacre NHS monument provides a location for solitude and contemplation to pay tribute to the fallen during the 1864 massacre.

Table 4.3.2-1. Characteristics of sound.

Characteristic	Low Sounds	Substantial Sounds
Loudness (Amplitude in dBA)	Natural quiet, nosie-free intervals, breathing, leaves rustling; The more distance between sound source and person/wildlife location, the lower the audibility	Aircraft overflights, high speed traffic, thunder; The closer the distance between sound source and person/wildlife location, the higher the audibility
Duration (Minutes/Seconds)	Sporadic, infrequent, irregular intervals	Frequent to constant
Rate of Occurrence	Few	Many
Pitch (Frequency in Hz)	Low pitch such as distant transportation	High pitch such as lawn mower at 1m

absorbed by the atmosphere or scattered by obstructions than low frequency sounds. Low frequency sounds diffract more effectively around obstructions. Therefore, low frequency sounds travel farther.

Besides the pitch of a sound, we also perceive the amplitude (or loudness) of a sound. This metric is decibels (dB). The decibel scale is logarithmic, meaning that every 10 dB increase in sound pressure level (SPL) represents a tenfold increase in sound energy. This also means that small variations in SPL can have significant effects on the acoustical environment. For instance, a 6 dB increase in a noise source will double the distance at which it can be heard, increasing the affected area by a factor of four. SPL is commonly summarized in terms of dBA (A-weighted SPL). This metric significantly discounts sounds below 1,000 Hz and above 6,000 Hz to approximate the variation in human hearing sensitivity.

In addition to loudness (amplitude) and pitch (frequency), the duration of sounds as well as number of times a particular sound is heard (i.e., rate of occurrence) influences whether sounds contribute or detract from a visitor's park experience or a wildlife species ability to communicate effectively. Table 4.3.2-1 lists the various characteristics of sounds that influence the quality of a soundscape.

Noise vs. Natural Sounds

When a sound is evaluated negatively, therefore undesirable, it is defined as noise (Morfey 2001). Conversely, (and for the purposes of this assessment) when sounds are evaluated from a positive perspective, we define those as "natural sounds" and/or sounds consistent with the designated use of a park area, such as Native American drumming or reenactments that may occur in cultural parks.

Natural sounds include those sounds upon which ecological processes and interactions depend. Examples of natural sounds in parks include:

- Sounds produced by birds, frogs or insects to define territories or attract mates
- Sounds produced by bats to navigate or locate prey
- Sounds produced by physical processes such as wind in trees, flowing water, or thunder.

Some common examples of noise often heard in parks include:

- Aircraft (i.e., high-altitude and military jets, fixed-wing, helicopters)
- Vehicles
- Generators
- Human voices.

Acoustical Environment

A park's natural acoustical environment is vital to its function and character, and in many parks, natural sounds often dominate the acoustical environment. However, human-caused noise has the potential to mask these natural sounds, and noise impacts the acoustical environment much like smog impacts the visual environment; obscuring

the listening horizon for both wildlife and visitors. But to determine that all natural sounds are good and all noise (human-produced) sounds are bad would be an overly simplistic approach to a fairly complex issue, such as evaluating the condition of a park's soundscape. Instead, for this assessment, we will identify the types of sounds and their associated loudness and other defining characteristics then evaluate whether those sounds heard, their levels, and characteristics such as duration, rate of occurrence, etc. are consistent with the designated uses at Sand Creek Massacre NHS.

To further compound a soundscape assessment, the types of sounds and their characteristics need to be evaluated by the various use areas that are common in parks. These acoustical areas may be characterized by the ambient conditions over the full extent of a park by dividing total area into "acoustic zones" on the basis of different vegetation zones, management zones, visitor use zones, elevations, or climate conditions. Then, the intensity, duration, and distribution of sound sources in each zone can be assessed by collecting SPL measurements and digital audio recordings within each of these zones.

Since the Historic Site is currently in the process of defining their management zones through their General Management Planning process, we have identified four common NPS management zones that are applicable to the Historic Site to use to determine whether the sounds heard at the park are consistent with current uses. These management zones and the common types of sounds and associated characteristics depending upon types of uses are listed in Table 4.3.2-2.

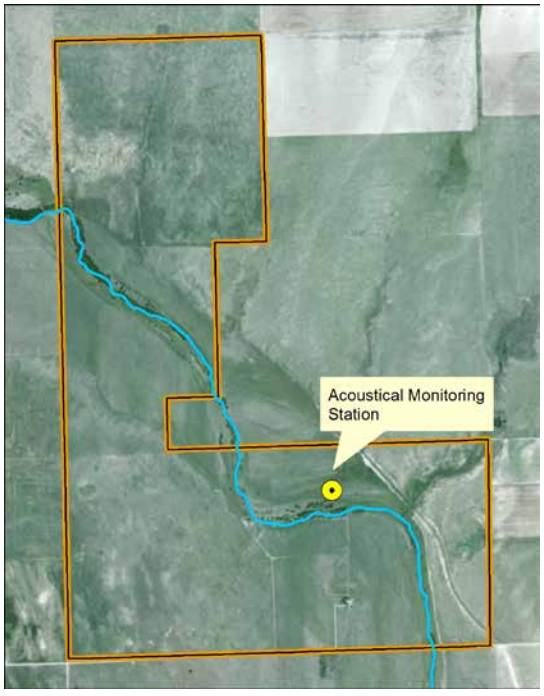


Figure 4.3.2-1. Location of acoustical monitoring station at the Historic Site.

Acoustical Monitoring at the Historic Site

Acoustical monitoring was conducted by the NSNSD at the Historic Site between 2009 and 2011 during summer and winter months to document seasonal variation of sounds (Lynch 2011). Summer monitoring occurred between July 13, 2009-August 26, 2009 for a total of 45 days. Winter monitoring occurred between January 13, 2011-February 14, 2011 for a total of 32 days.

Only one study location was chosen as the acoustical environment for both seasons since the location was representative of the dominant vegetation type found throughout the park-Blue grama with sage near riparian habitat along Sand Creek (Figure 4.3.2-1) (Lynch 2011).

The acoustical monitoring equipment used included a Type 1 sound level meter, which was configured to accept instantaneous wind speed, wind direction, temperature, and humidity, in real-time, from attached sensors and a 1⁄2" prepolarized, random-incidence microphone. The Larson Davis 831 sound level meter collected 33 1/3 octave sound pressure level measurements (in dB) every second from 12.5 Hz to 20,000 Hz, which encompasses the nominal range of human hearing. The microphone was deployed in an environmental housing with a wind screen at approximately 1.5 meters above ground (a close approximation of the average height of the human ear) (Lynch 2011).

According to Lynch (2011), "On-site listening is the practice of placing an observer near an acoustical monitoring station with a handheld Personal Digital Assistant (PDA). The observer listens for a designated period of time (generally one hour), and identifies all sound sources and their durations.

Table 4.3.2-2. Park acoustical environments presented by common management zones and associated sounds and sound characteristics as a result of typical designated activities.

Management Zone (Degree of Human Activity)	Typical Activities and Associated Sounds
Development (High Activity)	In this zone, the dominant sounds may be natural sounds when human-created sounds are absent (typically during low visitation, which occurs mostly during the winter months and at night), however, typical noises consistent with designated activities include normal conversation voices, voices from group gatherings, motorized vehicles driving by, short-duration idling, or starting/stopping of vehicles, periodic use of motorized tools and heavy equipment. Noise levels that interfere with wildlife behavior or auditory signals are generally infrequent but sometimes common. The sound levels are mostly comprised of the low-moderately high decibel producing sounds. Inappropriate noises in this zone include excessively loud voices (e.g., talking loudly or yelling), vehicles that are driving at excessive speeds or without properly functioning mufflers such that they can be heard more prominently, car horns, long durations of bus idling, and low flying aircraft.
Recreational (High-Medium Activity)	In this zone the dominant sounds most likely are comprised of the natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc., however, noises typical of designated activities include occasional voices from recreational activities including hiking and interpretive programs along the trails, occasional traffic noises, and occasional mechanized equipment noises, although, if audible, are more distant. Noise levels that interfere with wildlife behavior or auditory signals are infrequent to rare. The sound levels are almost exclusively comprised of the low-infrequently moderate decibel producing sounds. Inappropriate noises in this zone include hikers using excessively loud voices (e.g., talking loudly or yelling), vehicles that are driving at excessive speeds or without properly functioning mufflers such that they can be heard more prominently, and or increased starting and stopping or engines and car doors shutting, frequent mechanized equipment noise, and low to moderately low flying aircraft.
Resource (Cultural & Natural) (Medium-Low Activity)	In this zone the dominant sounds consistent with designated use range from the natural ambient sounds such as wind, leaves rustling, birds singing, thunder claps, etc. to sounds related to cultural activities. For example, tribal ceremonies or gatherings/activities to honor those fallen are consistent with designated activities even though these sounds may be louder. In absence of cultural events, faint noises can be heard but are typically infrequent. Noise levels that interfere with wildlife behavior or auditory signals are rare. The sound levels are typically comprised of the low decibel producing sounds, with the exception of thunderclaps and cultural events. Inappropriate noises in this zone include vehicles driving at excessive speeds or without properly functioning mufflers such that they can be heard more prominently, and low to high flying aircraft.
Conservation/Memorialization (Memorials & Habitat/Wildlife Areas) (Low Activity)	In this zone natural sounds and noise-free intervals dominate the landscape. If noises are audible, they occur in very short duration, infrequently, and are quite distant. Noise levels that interfere with wildlife behavior or auditory signals are infrequent to rare. This zone is managed for solitude and uninterrupted natural sounds that support wildlife survival and contemplation. Inappropriate noises include most human-generated noises, although characteristics of noises that lessen their intrusiveness are expected to be audible at times.

On-site listening takes full advantage of human binaural hearing capabilities, and closely matches the experience of park visitors. Logistical constraints prevent comprehensive sampling by this technique, but selective samples of on-site listening provide a basis for relating the results of off-site listening to the probable auditory perception of events by park visitors and wildlife." Numerous one-hour periods of on-site listening were conducted at the Historic Site in order to discern the type, timing, and duration of sound events. These data provided the basis for the calculation of percent time audible, the maximum, minimum, and mean length of sound sources, and standard deviation among sound event lengths. The number of times each sound source was audible was also recorded. Additionally, the noise free interval, which describes the length of time between extrinsic or human-caused sound events was recorded. The onsite listening provided an extensive inventory of sound sources and also provided a basis for relating the results of off site listening to the probable auditory perception of sound events by park visitors and wildlife (Lynch 2011).

Additionally, off site analysis was conducted by the NSNSD and provided a much wider picture of the acoustical environment (Lynch 2011). Once again, sound sources were recorded, but due to temporal variations in source audibility, results were reported by time category (e.g. day and night). Audibility results for all hours (00-23) were recorded

and audibility for different sections of the day and night was also recorded. Finally, an average count of sound events based upon sound sources per day was reported.

Indicators/Measures

Amount of Acoustical Environment Comprised of Natural Sound vs. Anthropogenic Noise

The first indicator we used was the amount of the Historic Site's soundscape comprised of natural versus anthropogenic noise.

Indicators/Measures

Are Types of Sounds Consistent with Designated Park Uses?

The second indicator used to assess the Historic Site's soundscape was based on whether the types of noises heard were expected for the Historic Site.

Indicators/Measures

Characteristics of Anthropogenic Noise

The third indicator used to assess the Historic Site's soundscape was based on whether the characteristics of noises heard, including sound level, pitch, duration, etc. were appropriate for the designated uses at the Historic Site.

4.3.3. Reference Conditions

Various characteristics of sound, including type of sound, rate of occurrence, duration, loudness, pitch, whether the sound occurs consistently or sporadically, and where these sound characteristics are heard, contribute to or detract from the condition of a park's soundscape. For example, a visitor may expect to hear car doors closing, human conversations, or park maintenance activities if these sounds occur within a highly visited area of the park, such as a visitor center parking lot. Conversely, if these same sounds and their associated characteristics occurred in an area where a visitor was seeking solitude, s/he would most likely not expect to hear these sounds and may perceive them as intrusive or disruptive to their desired experience.

In general, human responses to sound can actually serve as a proxy for potential impacts to other vertebrates because humans have more sensitive hearing at low frequencies than most species (Dooling and Popper 2007), so the time that sound pressure levels exceed those mentioned in Table 4.3.3-1. may provide insight to a park's soundscape condition. The first value (35 dBA) is designed to address the health effects of sleep interruption. Recent studies suggest that sound events as low as 35 dB can have adverse effects on blood pressure while sleeping (Haralabidis et al. 2008). The second threshold addresses the World Health Organization's recommendations that noise levels inside bedrooms remain below 45 dBA (Berglund et al. 1999). Park visitors camping in or near a park could experience either of these two effects. The third level (52 dBA) is based on the EPA's speech interference threshold for speaking in a raised voice to an audience at 10 meters. This threshold addresses the effects of noise on interpretive programs in parks. The final threshold (60 dBA) provides a basis for estimating impacts on normal voice communications at 1 meter. Hikers and visitors viewing scenic vistas in the park would likely be conducting such conversations.

Table 4.3.3-1. Effects of sound pressure levels (SPL) on humans

SPL (dBA)	Relevance
35	Blood pressure and heart rate increase in sleeping humans (Haralabidis et al., 2008)
45	World Health Organization's recommendation for maximum noise levels inside bedrooms (Berglund, Lindvall, and Schwela, 1999)
52	Speech interference for interpretive programs (U.S. Environmental Protection Agency, 1974)
60	Speech interruption for normal conversation (U.S. Environmental Protection Agency, 1974)

If we are to develop a complete understanding and assessment of a park's soundscape, we must not only consider a variety of sound characteristics but also answer the question of whether a certain sound and its associated characteristics are suitable to certain areas within a park. As a result, we differentiate between sound sources and their characteristics based upon designated activity areas (i.e., management zones) for our soundscape reference conditions, which are listed in Table 4.3.3-2.

We consider an ideal soundscape condition to be an area that is dominated by the natural ambient sound level, which refers to the acoustical conditions that exist in the absence of any human-caused noise and represents the base level from which the NPS NSNSD measures impacts to the acoustical environment regardless of park area. However, we realize that while no noise is ideal, it is extremely rare and unrealistic, especially when parks are also mandated to manage for various visitor uses. Instead, we have defined a good soundscape reference condition to be one that is consistent with designated activity-related noises within each management zone and where no excessive sound sources are present in any area of the park regardless of zone designation. Additionally, noise-free intervals will be quite common, even including the higher use zones due to seasonality of visitation and/or low visitation and daily visitor use patterns.

A moderate soundscape condition is one where the designated uses for higher activity zones begin to infiltrate into the lower use zones, noise-free intervals become only moderately common and higher level noises and associated characteristics (i.e., higher pitch, increased occurrence, longer duration, etc.) begin to be heard in all management zones.

A significant concern soundscape condition is when noises become incongruent with designated activities, such as military overflights, and noises and their associated characteristics infiltrate into all zones regardless of designated uses.

4.3.4. Condition and Trend

Amount of Acoustical Environment Comprised of Natural Sound vs. Anthropogenic Noise and Types of Sounds

The majority of sound sources and relative occurrences of each type of sound(s), including natural and non-natural (noise) at the Historic Site remained relatively similar throughout the summer and winter sampling periods. For example, during the summer sampling, birds (38%) and noise-free intervals (27%) represented 65% of the sound occurrences.

On-site analysis revealed that jets were the most commonly heard noise and were audible 13% and 18% during the summer and winter months, respectively. Additionally, during the winter months birds accounted for 37%, noise-free intervals accounted for 17%, and the wind accounted for 13% of the sound occurrences for a total of 67%. These few sound types for summer (n=3) and winter (n=4) represent 87% and 84% of the total number of sound sources/occurrences, respectively.

Off-site analysis conducted at Fort Collins, indicated that jets were audible approximately 24% of the time in the summer and approximately 22% of the time during the winter. These percentages are very similar regardless of season suggesting air traffic is fairly consistent throughout the year).

Overall, the majority of sounds recorded originated from natural sources. The recorded noises were for the most part congruent with current park activities, with the exception of aircraft noise.

Characteristics of Anthropogenic Noise

The existing ambient sound level, which refers to the current sound intensity of an area, including both natural and human-caused (noise) sounds, and the natural ambient sound level for the Historic Site is shown in Figure 4.3.4-1.

The natural ambient sound level at the Historic Site ranged from 15.7 dBA (nighttime winter)-18.6 (daytime winter) and from

Table 4.3.3-2. Reference conditions used to determine whether the condition of the soundscape at Sand Creek Massacre NHS is good, moderate, or of significant concern.

Zone	Sound Sources	Loudness	Duration	Rate of Occurrence	Pitch
Good					
Conservation/ Memorialization	Predominately nature sounds and natural quiet; some very distant noises	Low decibels in general, sometimes high decibels from singing birds or thunder claps	Long duration for nature sounds and noise free intervals, short noise duration	High number of nature sounds and noise-free intervals; low number of noises	High pitched sounds are from nature (e.g., crickets). No high pitched noises are heard.
Resources (Cultural/ Natural)	Predominately nature sounds and cultural-related sounds such as tribal ceremonies, drumming, and singing, etc.	Typically low decibel producing sounds but can be high if cultural events are occurring.	Dominated by long duration for nature sounds and noise free intervals, and typically shorter duration for cultural sounds (event driven).	High number of nature sounds and noise-free intervals; cultural-related sounds can also be high but likely infrequent; low number of noises	High pitched sounds are from nature and cultural-related activities (e.g., crickets, singing). No high pitched noises are heard.
Recreational	Predominately nature sounds, cultural-related sounds, and human conversations	Typically low decibel producing sounds but can be high if cultural events are occurring or groups are gathering.	Dominated by medium-long duration for nature sounds and noise free intervals, and typically shorter duration for conversations (event driven).	High number of nature sounds and noise-free intervals. At times, there is a higher number of voices heard, but likely infrequent and grouped.	High pitched noises occur from nature sounds. An occasional shout can be heard.
Development	Noises include vehicles, human voices, park maintenance activities, although nature sounds may also be heard.	Can range from high to low decibels.	Short-medium noise duration and any duration of natural sounds is considered good.	Higher number of human-generated activities are heard, such as vehicle start/ stop, equipment use, and human activities.	Low-high pitch sounds can be heard for both noises and natural sounds.
Moderate					
Conservation/ Memorialization Resources Recreational Development	A moderate soundscape condition is one where the designated uses for higher activity zones (e.g., development and recreational) begin to infiltrate into the lower use zones (e.g., conservation, resources) as shown by the yellow arrow increasing from the development zone into the quieter zones, noise-free intervals become only moderately common and higher level noises and associated characteristics (i.e., higher pitch, increased occurrence, longer duration, etc.) begin to be heard in all management zones.				
Significant Concern					
Conservation/ Memorialization Resources Recreational Development	A significant concern soundscape condition is one where noises become incongruent with all designated activities regardless of zone designation. A good example is the loud noise generated from military overflights infiltrating all areas of the park. A significant concern condition is also warranted when the noises generated within the development or recreational zones become commonly heard in the lower use zones (e.g., conservation, resources).				

Note: In general, the soundscape condition becomes progressively worse when the higher activity zone noises and their associated characteristics, such as loudness, pitch, duration, and rate of occurrence, infiltrate the lower activity zones. Sounds of nature and noise-free intervals become increasingly rare. However, the soundscape condition is considered good if the lower activity zone noises and their associated sound characteristics infiltrate the higher activity zones, which would result in an overall quieter soundscape. In addition, noises produced by the various types of aircraft affects all zones but is considered more detrimental when heard in the zones designated for solitude/contemplation and resources management.

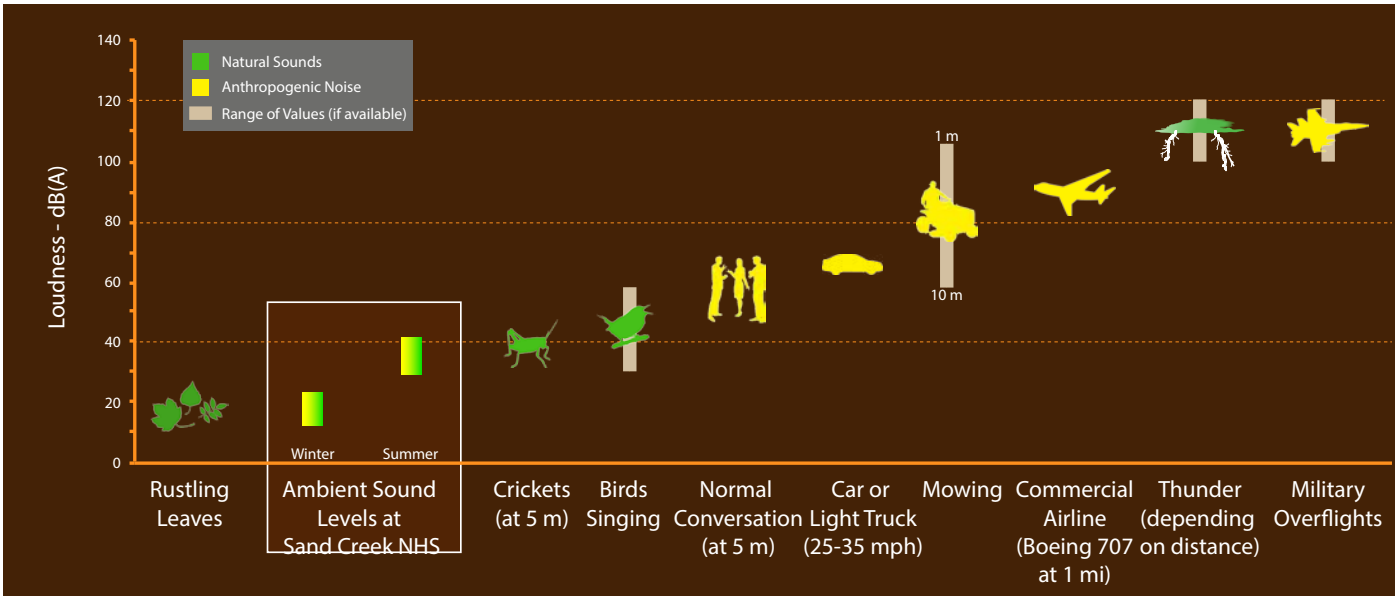


Figure 4.3.4-1. Approximate sound levels for common sounds, including noise, likely to be heard at Sand Creek Massacre NHS and acoustical monitoring results for the Historic Site.

32.3 dBA (nighttime summer) - 36.6 dBA (daytime summer) (Emma Lynch, pers. comm. Note: the results reported in Lynch 2011 were accidentally reported incorrectly). Sometimes during both winter day and night the sound levels were lower than what could be perceived by the average human ear (Lynch 2011).

The existing ambient levels ranged from 16.0 dBA (nighttime winter)-20.8 (daytime winter) and from 33.6 dBA (nighttime summer) - 38.8 dBA (daytime summer) (Emma Lynch, pers. comm. Note: the results reported in Lynch 2011 were accidentally reported incorrectly). The NSNSD tracked noise audibility on an hourly basis and reported it as the percent of the hour in which noise could be heard. In the summer this ranged from 13.1% to 63% (Figure 4.3.4-2) and in the winter it ranged from 11.5%-55.6% (Figure 4.3.4-3).

Some seasonal variations in noises heard included increased park maintenance operations and adjacent agricultural activities such as cows grazing, both occurring during the summer monitoring period. But overall, many of the summer noises were masked by rustling leaves, bird songs, and insects, which were louder.

Fewer masking sounds existed during the winter monitoring period so listeners would hear more non-natural noises for longer periods of time, such as the distant oil well pump jack located 2 miles northeast that was audible an average of 5.5% of the time between 7pm and 7am during the winter monitoring period and wasn't heard at all during the summer monitoring period (Lynch 2011).

Noise generated from commercial jet traffic was consistent across both seasons. The Historic Site's proximity to Denver International Airport is a likely reason so many jets can be heard consistently within the park.

The duration of the predominant noise-generating sounds heard differed between the summer and winter sampling periods. For example, the mean amount of time commercial jets were heard during the winter sampling period as compared to the summer sampling period was almost 4 minutes longer and was audible for 73% of the time overall as compared to 13% audible during the summer sampling period. The mean event time for aircraft with propellers was longer in the winter and could be heard for 2 minutes in the winter compared to 55 seconds during the summer monitoring period. In addition, more unidentifiable non-natural producing sounds were heard during the winter sampling period as compared to none during the summer.

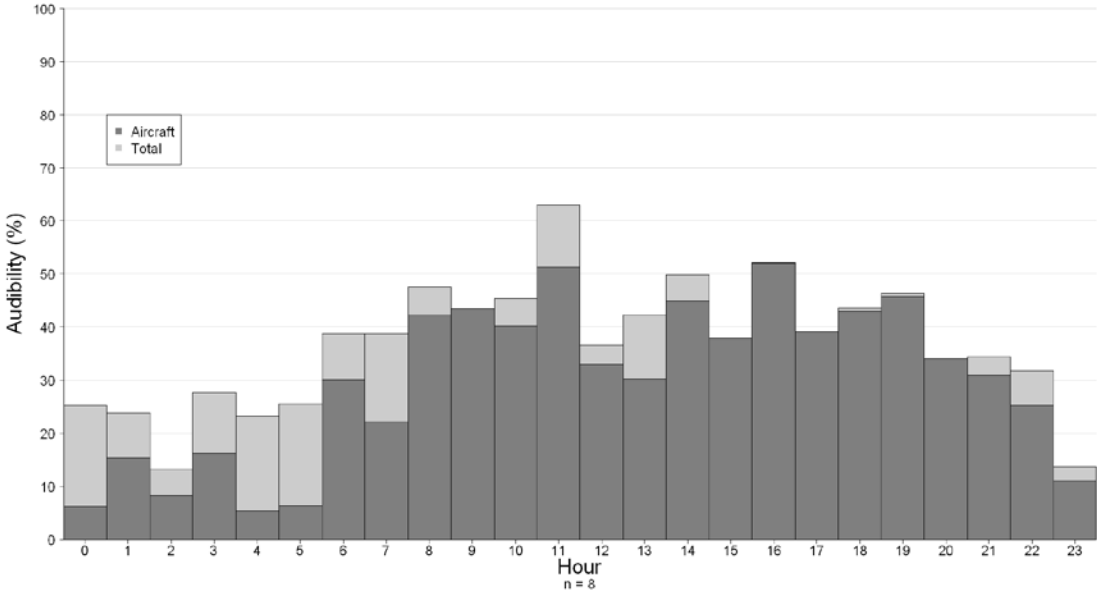


Figure 4.3.4-2. Percent time (by hour) sounds were audible during the summer monitoring period.

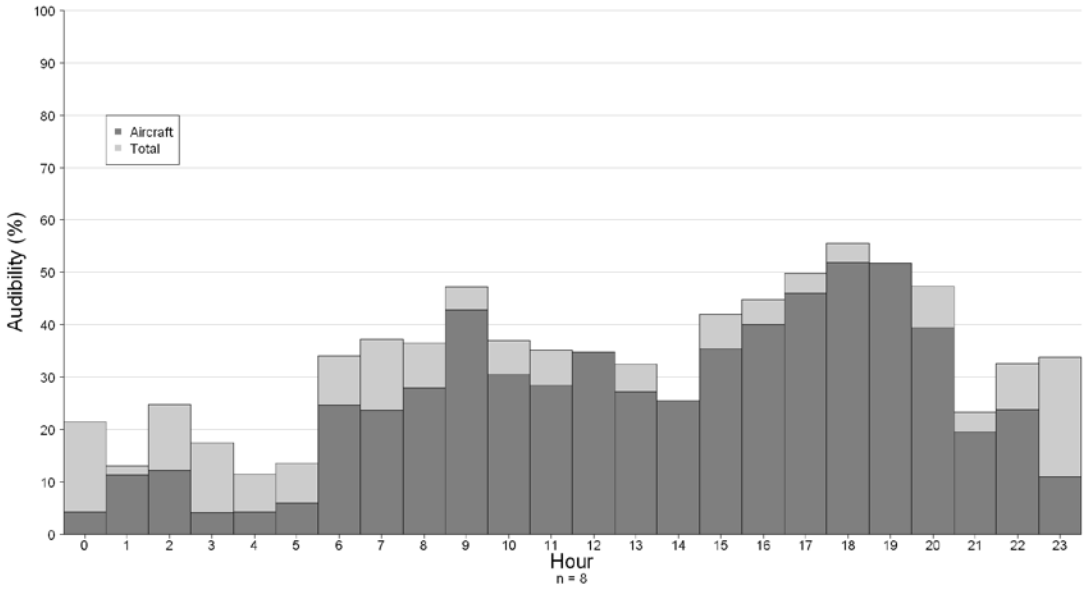


Figure 4.3.4-3. Percent time (by hour) sounds were audible during the winter monitoring period..

These duration results do not imply that more noise-generating activities occurred during the winter months, rather the masking effects of sounds such as insects and wind were less audible in the winter as compared to the summer (Lynch 2011).

Another sound characteristic contributing to soundscape condition is pitch or frequency. Both high and low frequency sounds occur simultaneously and are rarely constant but more likely sporadic. At the Historic Site, there were daytime peaks of high frequency sounds due to insects and singing birds. During the winter monitoring, high frequency sounds were generally lower, and at certain times, sound levels in certain frequencies were lower than what the average human could hear (Lynch 2011).

Lynch (2011) also noted that there is evidence suggesting that masking effects from a combination of vehicles, wind, and running water can at times, mask the sound from distant aircraft, which is relevant to the Historic Site's soundscape given the fact that aircraft is consistently heard.

Table 4.3.4-1. Summary of the soundscape indicators/measures and their contributions to the overall soundscape condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Amount of Acoustical Environment Comprised of Natural Sound vs. Anthropogenic Noise	91% of NPS visitors consider enjoyment of natural sounds and quiet, are compelling reasons for visiting national parks. Additionally, natural sound plays a critical role for several species' survival.	Natural sounds and noise-free intervals dominated the acoustical environment at the Historic Site. Sometimes the sounds were so low that they were nearly beyond the sound monitoring equipment's capability to record.
Are types of noises consistent with designated park uses?	Not all noises are a nuisance and many anthropogenic noises are expected based upon the area of the park in which they are heard.	In general, the types of noises heard, including cows from adjacent lands and park maintenance activities were expected. Largely absent were noises generated from vehicles. Instead the most common anthropogenic noise was generated from commercial jets.
Characteristics of Anthropogenic Noise	Noise is comprised of several characteristics including loudness (sound level), duration, pitch (frequency), and rate of occurrence.	More noise could be heard during the summering monitoring period due to increased activity both within and outside of the Historic Site. The duration of noises was longer during the winter monitoring period, which was in large part, due to the effects of masking by increased biologic activity that occurred during the summer months. In general, the predominant sound characteristics recorded were from natural sound sources.

Overall Condition and Trend

Overall, the soundscape at the Historic Site is in good condition (Table 4.3.4-1), but long-term data are unavailable to determine trend at this time.

As stated previously, the range of values for the existing ambient levels at the Historic Site, which included both anthropogenic noises and natural sounds, was 16.0 dBA (nighttime winter)-20.8 (daytime winter) and from 33.6 dBA (nighttime summer) - 38.8 dBA (daytime summer). These results are below the World Health Organization's recommendation for maximum noise levels inside bedrooms, thus considered quiet.

During both sampling periods, natural sounds and noise-free intervals dominated the soundscape at the Historic Site. The daytime hours were most affected by anthropogenic noise, but at times, noises from commercial jets could still be heard during the nighttime hours. In addition, acoustical conditions were considerably quieter in the winter as compared to summer. Some of the measured sound levels were near the lowest recording limit of the monitoring equipment during the winter nighttime and early morning hours (Lynch 2011). The higher levels of sounds heard throughout the summertime was due to the increased biologic activity (e.g., birds singing, insect sounds, etc.). Even though the Historic Site's acoustical environment was comprised predominantly of natural sources from wildlife, vegetation, insects, and wind, these sounds are also consistent with the Historic Site's cultural soundscape. They provide a physical connection to the cultural significance of the site, and even though the cultural soundscape is heard primarily as the natural ambient level, sounds from cultural

ceremonies or other activities would also be considered as contributing to a good soundscape condition (Figure 4.3.4-4).

Level of Confidence

NPS' Natural Sounds and Night Skies Division (NSNSD) conducted the soundscape assessment to evaluate the condition of the Historic Site's soundscape. Based on the expertise of the NSNSD, we're confident that the findings accurately reflected the condition of the Historic Site's soundscape at the time of the assessment, therefore, the confidence level is high.

Key Uncertainties

A common source of noise in national parks is transportation (i.e., airplanes, vehicles). Growth in transportation is increasing faster than is the human population (Barber et al. 2010). Between 1970 and 2007, traffic on US roads nearly tripled to almost 5 trillion vehicle km/yr (USDOT 2013a). Aircraft traffic grew by a factor of three or more between 1981 and 2007 (USDOT 2013b). As these noise sources increase throughout the United States, the ability to protect pristine and quiet natural areas becomes more difficult (Mace et al. 2004).

While few vehicles were heard at the Historic Site since visitation is relatively low, noise from aircraft was quite prominent. With the Historic Site's proximity to the Denver International Airport, commercial jet traffic is consistently high throughout both seasons and even into the nighttime hours (Lynch 2011).

With respect to the effects of noise, while there is compelling evidence that wildlife can suffer adverse behavioral and physiological changes from intrusive sounds (noise) and other human disturbances, the ability to translate that evidence into quantitative estimates of impacts is presently limited. Several recommendations have been made for human exposure to noise, but no guidelines exist for wildlife and the habitats we share. The majority of research on wildlife has focused on acute noise events, so further research needs to be dedicated to chronic noise exposure (Barber et al. 2011). In addition to wildlife, standards have not been developed yet for assessing the quality of physical sound resources (the



Figure 4.3.4-4. Cultural sounds, such as drumming, are consistent with the Historic Site's good soundscape condition.

acoustical environment), separate from human or wildlife perception. Scientists are also working to differentiate between impacts to wildlife that result from the noise itself or the presence of the noise source.

4.3.5. Sources of Expertise

The NPS Natural Sounds and Night Skies Division scientists help parks manage sounds in a way that balances the various expectations of park visitors with the protection of park resources. They provide technical assistance to parks in the form of acoustical monitoring, data collection and analysis, and in developing acoustical baselines for planning and reporting purposes.

The NSNSD also provided a NRCA soundscape template, which we largely used to develop Sand Creek Massacre NHS' soundscape assessment. For more information, see http://www.nature.nps.gov/sound/.

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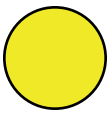
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4.4. Air Quality

Indicators/Measures

- Visibility haze index
- Level of ozone
- Atmospheric wet deposition in total N and total S

Condition - Trend - Confidence



Moderate - Insufficient Data - Medium

4.4.1. Background and Importance

Under the direction of the NPS' Organic Act, Air Quality Management Policy 4.7.1 (NPS 2006), and the Clean Air Act (CAA) of 1970 (U.S. Federal Register 1970), the NPS has a responsibility to protect air quality and any air quality related values (e.g., scenic, biological, cultural, and recreational resources) that may be impaired from air pollutants.

One of the main purposes of the CAA is "to preserve, protect, and enhance the air quality in national parks" and other areas of special national or regional natural, recreational, scenic or historic value. The CAA includes special programs to prevent significant air quality deterioration in clean air areas and to protect visibility in major national parks and wilderness areas (NPS-ARD 2012a).

Different categories of air quality areas have been established through the authority of the CAA: Class I, II, and III. Like most National Park Service areas, Sand Creek Massacre National Historic Site is designated as a Class II airshed (Figure 4.4.1-1).

These classes are allowed different levels of permissible air pollution, with Class I receiving the greatest protection and strictest regulation. The CAA gives federal land managers responsibilities and opportunities to participate in decisions being made by regulatory agencies that might affect air quality in the federally protected areas they administer (NPS-ARD 2012b).

It's important to note that even though the CAA gives Class I areas the greatest protection against air quality deterioration, NPS management policies do not distinguish between the level of protection afforded to any unit of the National Park System (NPS 2006).

Air Quality Standards

Air quality is deteriorated by many forms of pollutants that either occur as primary pollutants, emitted directly from sources such as power plants, vehicles, wildfires, and wind-blown dust, or as secondary pollutants, which result from atmospheric chemical reactions. The CAA requires the Environmental Protection Agency (EPA) to establish National Ambient Air Quality Standards (NAAQS) (40 CFR part 50) to regulate these air pollutants that are considered harmful to human health and the environment (EPA 2012a). The two types of NAAQS are primary and secondary, with the primary standards establishing limits to protect human health, and the secondary standards establishing limits to protect public welfare from air pollution effects, including



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Figure 4.4.1-1. Sand Creek Massacre National Historic Site is a Class II airshed.



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Figure 4.4.1-2. A clear day at Sand Creek Massacre National Historic Site.

decreased visibility, damage to animals, crops, vegetation, and buildings (EPA 2012a).

The NPS' Air Resources Division (NPS-ARD) air quality monitoring program uses EPA's NAAQS, natural visibility goals, and ecological thresholds as benchmarks to assess current conditions of visibility, ozone, and atmospheric deposition throughout park service areas.

Visibility affects how well (acuity) and how far (visual range) one can see (NPS-ARD 2002), but air pollution can degrade visibility. Both particulate matter (e.g. soot and dust) and certain gases and particles in the atmosphere, such as sulfate and nitrate particles, can create haze and reduce visibility.

Visibility can be subjective and value-based (e.g. a visitor's reaction viewing a scenic vista while observing a variety of forms, textures, colors, and brightness) (Figure 4.4.1-2) or it can be measured objectively by determining the size and composition of particles in the atmosphere that interfere with a person's ability to see landscape features (Malm 1999). The viewshed section (4.1) of this assessment addresses the subjective aspects of visibility, whereas, this section addresses measurements of particles and gases in the atmosphere affecting visibility.

Ozone is a gaseous constituent of the atmosphere produced by reactions of nitrogen oxides (NO_x) from vehicles, powerplants, industry, and fire and volatile organic compounds from industry, solvents, and vegetation in the presence of sunlight (Porter and Biel 2011). It is one of the most widespread air pollutants (NPS-ARD 2003), and the major constituent in smog. Ozone can be harmful to human health, and it is also phytotoxic, causing foliar damage to plants (NPS-ARD 2003). The foliar damage requires the interplay of several factors, including the interaction of the plant to the ozone, the level of ozone exposure, and the exposure environment. The highest ozone risk exists when the species of plants are highly sensitive to ozone, the exposure levels of ozone significantly exceed the thresholds for foliar injury, and the environmental conditions, particularly adequate soil moisture, foster gas exchange and the uptake of ozone by plants (Kohut 2007).

Ozone penetrates leaves through stomata (openings) and oxidizes plant tissue, which alters the physiological and biochemical processes (NPS-ARD 2012c). Once the ozone is inside the plant's cellular system, the chemical reactions can cause cell injury or even death (NPS-ARD 2012c), but more often reduces the plant's resistance to insects and diseases, reduces growth, and reduces reproductive capability (NPS-ARD 2012d).

Air pollutants can be deposited to ecosystems through rain and snow (wet deposition) or dust and gases (dry deposition). Nitrogen and sulfur air pollutants are commonly deposited as nitrate, ammonium, and sulfate ions and can have a variety of effects on ecosystem health, including acidification, fertilization or eutrophication, and accumulation of toxins (NPS-ARD 2010a). Atmospheric deposition can also change soil pH, which in turn, affects microorganisms, understory plants, and trees (NPS-ARD 2010a). Certain ecosystems are more vulnerable to nitrogen or sulfur deposition than others, including high-elevation ecosystems in the western United States, upland areas in the eastern part of the country, areas on granitic bedrock, coastal and estuarine waters, arid ecosystems, and some grasslands (NPS-ARD 2010b). Increases in N have been found to promote invasions of fast-growing annual grasses (e.g., cheatgrass) and exotic species (e.g., Russian thistle) at the expense of native species (Brooks 2003, Allen et al. 2009, Schwinning et al. 2005). Increased grasses can increase fire risk (Rao et al. 2010), with profound implications for biodiversity in non-fire adapted ecosystems. N may also increase water use in plants like big sagebrush (Inouye 2006).

According to the EPA, in the United States, roughly two thirds of all SO_2 and one quarter of all NO_x come from electric power generation that relies on burning fossil fuels. Sulfur dioxide and nitrogen oxides are released from power plants and other sources, and ammonia is released by agricultural activities, feedlots, fires, and catalytic converters. In the atmosphere these transform to sulfate, nitrate, and ammonium and can be transported long distances across state and national borders, impacting resources in remote areas, including Sand Creek Massacre National Historic Site (EPA 2012b).

4.4.2. Data and Methods

The approach we used for assessing the condition of air quality within the Historic Site's airshed was developed by the NPS-ARD for use in Natural Resource Condition Assessments (NPS-ARD 2010b, 2010c). Interpolated values generated by NPS-ARD, averaged over five years were used to assess condition. NPS-ARD used all available data from NPS, EPA, state, tribal, and local monitors to generate the interpolated values across the contiguous U.S., with a specific value assigned to the center of each park. These values provided estimates for visibility, ozone, and atmospheric wet deposition in the absence of onsite monitoring. Even though the data are derived from all available monitors, the data from the closest monitor will "outweigh" the rest.

Indicators/Measures

Visibility Haze Index

Visibility is monitored by the Interagency Monitoring of Protected Visual Environments (IMPROVE) Program (NPS-ARD 2010a). The NPS-ARD assesses visibility based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions; (i.e., those estimated for a given area in the absence of human-caused visibility impairment, EPA-454/B003-005). Group 50 is defined as the mean of the visibility observations falling within the range of the 40th through the 60th percentiles, as expressed in terms of a Haze Index in deciviews (dv). A factor of the haze index is light extinction, which is used as an indicator to assess the quality of scenic vista and is proportional to the amount of light lost due to scattering or absorption by particles in the air as light travels a distance of one million meters (NPS-ARD 2003). The haze index for visibility condition is calculated as follows:

Visibility Condition/Haze Index (dv) = current Group 50 visibility – estimated Group 50 visibility (under natural conditions)

The deciview scale scores pristine conditions as a zero and increases as visibility decreases (NPS-ARD 2010b).

Indicators/Measures

Level of Ozone

Ozone is monitored as part of the NPS Gaseous Pollutant Monitoring Program, in partnership with the EPA's CASTNet

Program (Porter and Biel 2011). The assessment for ozone levels at the Historic Site was made by referencing NPS ARD's five-year interpolated values.

Indicators/Measures

Atmospheric wet deposition in total N and total S

Atmospheric deposition can be monitored in both wet and dry forms, but for the purposes of this assessment, we will use wet deposition monitoring data only because most areas of the country do not have dry deposition data available, including the Historic Site.

Atmospheric wet deposition is monitored across the United States as part of the National Atmospheric Deposition Program/ National Trends Network (NADP/NTN; NPS-ARD 2003). The values for wet deposition condition are expressed as the average amount of nitrogen (N) or sulfur (S) in kilograms deposited over a one-hectare area in one year (kg/ha/yr) (NPS-ARD 2003).

4.4.3. Reference Conditions

The reference conditions against which current air quality indicators are assessed are identified by NPS ARD (2010b) for NRCAs and listed in Table 4.4.3-1.

Visibility

A visibility condition estimate of less than 2 dv above estimated natural conditions indicates a "good" condition, estimates ranging from 2-8 dv above natural conditions indicate "moderate" condition, and estimates greater than 8 dv above natural conditions indicate "significant concern." Although the dv ranges of these categories were selected somewhat subjectively, the NPS-ARD chose them to reflect the variation in visibility conditions across the monitoring network as closely as possible.

Ozone

The ozone standard set by the EPA at a level to protect human health, 75 parts per billion (ppb) averaged over an eight-hour period, is used as a benchmark for rating current ozone condition. The three-year average of the fourth-highest daily maximum eight-hour average ozone concentrations measured at each monitor in an area must not exceed 75 ppb in order to be in compliance with the EPA standard.

The NPS-ARD rates ozone condition as "good" if the ozone concentration is less than or equal to 60 ppb, "moderate" if the ozone concentration is between 61 and 75 ppb, and of "significant concern" if the concentration is greater than or equal to 76 ppb.

Wet Deposition

The NPS-ARD considers parks with less than 1 kg/ha/yr of atmospheric wet deposition of nitrogen or sulfur compounds to be in "good" condition, those with 1-3 kg/ha/yr to be in "moderate" condition, and parks with wet deposition greater than 3 kg/ha/yr to be of "significant concern."

4.4.4. Condition and Trend

Condition for all air quality indicators are listed in Table 4.4.4-1.

Visibility

All visibility data were derived from NPS ARD Air Atlas interpolated five-year average values (2005-2009) (D. Bingham, pers. comm.). The 5-year interpolated values average for the Historic Site's visibility condition fell within the moderate condition rating, which indicates visibility is degraded from the good reference condition of <2 dv above the natural condition. No visibility trend was reported specifically for Sand Creek Massacre NHS, but in considering the overall trend of visibility throughout national

Table 4.4.3-1. Reference conditions for air quality indicators.

Air Quality Indicator	Significant Concern	Moderate	Good
Visibility	>8 dv	2-8 dv	< 2 dv
Ozone	≥ 76 ppb	61-75 ppb	≤ 60 ppb
Wet deposition (total N and total S)	>3 kg/ha/yr	1-3 kg/ha/yr	< 1 kg/ha/yr

Source: NPS-ARD 2010b

Table 4.4.4-1. Condition results for air quality indicators at Sand Creek Massacre NHS.

Data Span	Ozone	Visibility	Total N (kg/ha)	Total S (kg/ha)
2005-2009	Moderate	Moderate	Moderate	Good

Source: D. Bingham, NPS-ARD

Table 4.4.4-2. Ozone sensitive plants found at Sand Creek Massacre NHS (NPS-ARD 2006).

Scientific Name	Common Name	Bioindicator
Apios americana	Groundnut; Indian Potato	Yes
Apocynum cannabinum	Indianhemp	No

parks, NPS-ARD analyzed visibility data for 157 parks during the period of 1999-2008. Only five of the parks showed a significant degrading trend on either clear or hazy days, with none of those parks located west of the Mississippi River, except for Hawaii (NPS-ARD 2010a). The majority of the parks measured during the haziest days revealed no visibility trend (NPS-ARD 2010a).

Ozone

All ozone data for the Historic Site were derived from the five-year interpolated values average (2005-2009) (D. Bingham, NPS-Air Resources Condition, pers. comm.), which resulted in a moderate ozone condition ranking for Sand Creek Massacre NHS.

By comparing the Historic Site's plant list (Certified Species List 2009) against ozone-sensitive plant species identified by Porter (2003), two plant species found within Sand Creek Massacre NHS are ozone-sensitive (NPS-ARD 2012e). In addition, one of those plants, Groundnut, is an ozone bioindicator (Table 4.4.4-2). In order to be considered as an ozone bioindicator most of the following criteria must be met:

- species exhibit foliar symptoms in the field at ambient ozone concentrations that can be easily recognized as ozone injury by subject matter experts
- species ozone sensitivity has been confirmed at realistic ozone concentrations in exposure chambers
- species are widely distributed regionally
- species are easily identified in the field (NPS-ARD 2012e).

An example of foliar damage from ozone is shown on a Groundnut plant in Figure 4.4.4-1 (NPS-ARD 2012f).



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Figure 4.4.4-1. Ozone Injury to Groundnut.

Wet Deposition

The data for atmospheric wet deposition condition were derived from NPS-ARD's 2005-2009 interpolated values (D. Bingham, NPS, pers. comm.). The average value for total nitrogen resulted in moderate condition rating and the condition rating was good for total sulfur.

In general, nitrate, sulfate, and ammonium deposition levels have changed over the past 20 years throughout the United States (Figure 4.4.4-2). Regulatory programs that mandated a reduction in emissions have proven effective for decreasing both sulfate and nitrate ion deposition primarily through reductions from electric utilities, vehicles, and industrial boilers, although a rise in ammonium ion deposition has occurred in large part due to the agricultural and livestock industries (NPS-ARD 2012g). A new study conducted by Lehmann and Gay (2011), indicated a decrease in sulfate concentrations

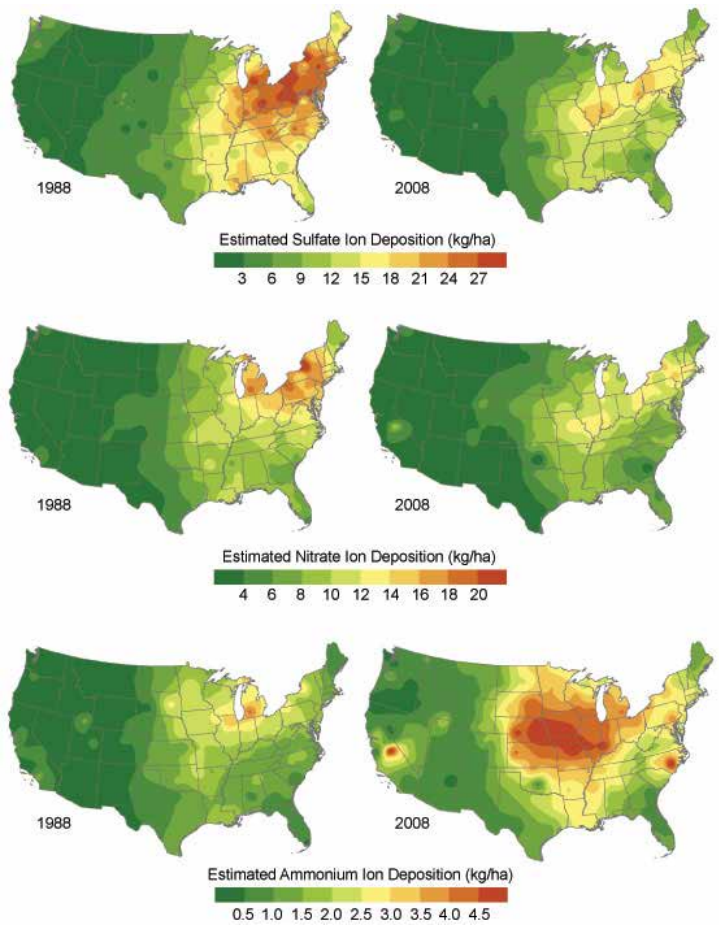


Figure 4.4.4-2. Change in wet deposition levels From 1988-2008 throughout the United States.

from 1985-2009 in the area surrounding the Historic Site, and a potential decrease in nitrate concentrations. The observed decrease was statistically significant for sulfate concentrations.

It seems reasonable to expect a continued improvement in sulfate deposition levels because of Clean Air Act requirements, however, at this time, ammonium levels are not regulated by the EPA and may continue to rise as a result (NPS-ARD 2010a).

Overall Condition and Trend

For assessing the condition of air quality, we used three air quality indicators/measures. Our indicators/measures for this resource were intended to capture different aspects of air quality, and a summary of how they contributed to the overall condition is summarized in Table 4.4.4-3.

We consider the overall condition of air quality at Sand Creek Massacre National Historic Site to be of a moderate concern. Trends cannot be derived since air quality monitoring sites are not located near enough to be representative of the conditions at the Historic Site and onsite monitoring does not occur. A monitor is considered representative if it is located within 10 miles for ozone and within 100 km for visibility

Level of Confidence/Key Uncertainties

The key uncertainty of the air quality section is knowing the effect(s) of air pollution, especially nitrogen deposition, on ecosystems at Sand Creek Massacre NHS.

4.4.5. Sources of Expertise

The National Park Service's Air Resources Division oversees the national air resource management program for the NPS. Together with parks and NPS regional offices, they monitor air quality in park units; provide air quality analysis and expertise related to all air quality topics.

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Table 4.4.4-3. Summary of the air quality indicators/measures and their contributions to the overall air quality Natural Resource Condition Assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Visibility haze index	Visibility affects how well and how far one can see and is negatively affected by air pollution. Particulate matter, gases, and particulates can create haze thereby reducing visibility. NPS visitor studies have shown the importance visitors place on their ability to view the scenic vistas within and throughout national parks.	Five-year average of interpolated visibility values were derived to determine that the condition of visibility is of moderate concern at the Historic Site.
Level of ozone	Ozone is an atmospheric gas that is produced by reactions of nitrogen oxides and is one of the most widespread air pollutants. Ozone can be harmful to human heath as well as to vegetation by causing foliar damage, which sometimes leads to the death of the affected plant(s).	Five-year average of interpolated ozone values were derived to determine that the condition of ozone is of moderate concern at the Historic Site. In addition, two plant species have been identified as ozone sensitive, four of which serve as bioindicators.
Atmospheric wet deposition in total N and total S	Air pollutants can be deposited to ecosystems through rain and snow, which is referred to as atmospheric wet deposition. Nitrogen and sulfur air pollutants are commonly deposited onto ecosystems sometimes resulting in acidification, fertilization, eutrophication, or accumulation of toxins.	Five-year average of interpolated atmospheric wet deposition values were derived to determine that the condition of total nitrogen is of moderate concern and the condition of total sulfur is good at the Historic Site.

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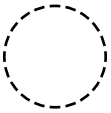
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4.5. Geology

Indicators/Measures

- No indicators or measures identified

Condition - Trend - Confidence



Insufficient Data - Insufficient Data - Low

4.5.1. Background and Importance

Sand Creek Massacre National Historic Site (NHS) is located in the Big Sandy drainage in southern Colorado and includes about seven miles of the creek's lower reaches, several miles above the confluence with Rush Creek (Martin et al. 2012). The topography at Sand Creek Massacre NHS consists of gently undulating hills comprised of sand plains stabilized by vegetation, aeolian deposits, and smooth plains. The Historic Site is bisected by Big Sandy Creek. North and east of the creek the landscape is dominated by smooth plains where grassland occurs. To the south and west are irregularly surfaced sand hills stabilized by sand sage shrub land.

The Sand Creek valley is carved out of thick marine Cretaceous shale including the Pierre Shale, Niobrara Formation, and Carlile Shale. They are relatively impermeable (Martin et al. 2012). The formations may be up to 4,000 feet thick. In the Historic Site area, the Cretaceous rocks are buried by Quaternary (ranging in age from about 2 million years old to recent) deposits, primarily loess and aeolian sand. The Late Cretaceous rocks are located in limited exposures east and northeast of Big Sandy Creek. South and west of Big Sandy Creek is Quaternary age dune sand, comprised of approximately 75% very fine to medium sand and 25% coarse sand. Big Sandy Creek and its tributaries' riparian corridor is comprised of Quaternary alluvium deposits that underwent successive periods of deposition and erosion, resulting in at least four terraces above the current floodplain. More modern floodplain deposits are reflected in three terraces deposited within the past 2,500 years.

The Cretaceous shale layers were originally deposited in an extensive inland seaway that bisected North America from about 100 to 70 million years ago. Subsequent continental uplift and volcanism lead both to the draining of the inland sea and creation of mountain ranges to the west. Material eroded from these mountains during the Tertiary Period (about 30 to 20 million years ago) fanned out onto the plains covering eastern Colorado (including the future Sand Creek Massacre NHS site) and formed the Ogallala Formation, an alluvial-derived heterogeneous group of sandstones. About five to ten million years ago, additional uplift resulted in the proto-South Platte and Arkansas rivers eroding broad valleys out on the plains. During Quaternary time (beginning about 2 million years ago), alternating wet and dry periods generated deposition and erosion cycles which augmented the Great Plains landscape by creating a sequence of terraces in the riparian drainages that are distinguishable by their different sediment characteristics (Sovell et al. 2008).

Geology, and associated soils, are the basis for vegetation communities, the hydrology, and the basic landforms and topography for an area, that then support the biotic communities. Soils, hydrology, and landform also influence human settlement patterns, and how people use the land--for farming, ranching, hunting, fishing, and other basic land uses.



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The bluffs along Sand Creek are geologic features of historical significance, and may warrant additional attention.

4.5.2. Data and Methods

This limited assessment is based on a geology and groundwater study (Coffin 1967) and several brief background descriptions of the geology included in reports on riparian condition (Martin et al. 2012) and a rare species inventory (Sovell et al. 2008). The geology and groundwater study, conducted in cooperation with the Colorado Water Conservation Board, began in July 1959 and field data were collected in 1962.

A geoarchaeological assessment was also conducted in 1998 by the Laramie Soils Service (Holms and McFaul 1999). The purpose of that assessment was to assist the National Park Service and the Cheyenne and Arapaho tribes to determine if undisturbed geological deposits from the 1864 period were present. In that study, they collected and examined core samples from 27 locations in 1998 and 37 additional core samples in 1999.

4.5.3. Condition and Trend

The geoarchaeological assessment determined that due to the relatively gentle nature of eolian deposition and age of the sediments, there is a high probability they can yeild *in situ* 1864-period artifacts, although none were recovered during the collection of core samples (Holmes and McFaul 1999). [Scott and others (1998) did recover artifacts in the eolian sands during a 1997 archaeological survey.] Holmes and McFaul concluded there was little subsurface disturbance; only minimal areas of possible plow zones.

Specific indicators and measures related to soil erosion are presented in section 4.9 on grasslands.

The bluffs along Sand Creek are topographic features of interest with historic significance and may warrant additional investigation.

This section is a summary of existing, limited information; no geologic assessment has been completed for Sand Creek Massacre NHS, and this remains a data gap.

4.5.4. Sources of Expertise

This section was reviewed and edited by Bruce Heise and Jason Kenworthy, Geologists at the National Park Service Geological Resources Division.

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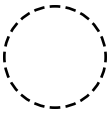
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4.6. Surface Water Quality

Indicators/Measures

- Water Quality (5 indicators)

Condition – Trend - Confidence



Insufficient Data - Insufficient Data - Low

4.6.1. Background and Importance

Streams and rivers are the integrators within a landscape. They depend upon inputs, such as energy and nutrients, from within their watershed, which in turn, support a wide variety of services including habitat for plants and animals, hydrologic cycling, nutrient processing, recreational opportunities, as well as water supply for public and private uses. Since streams and rivers are generally sensitive to stressors, both locally and at the watershed-level, they are one of the most useful ecosystems to monitor to determine long-term conditions and trends (NPS 2012).

NPS Management Policies (2006) state that parks must work with other governmental agencies to obtain Clean Water Act standards, take necessary action to maintain or restore surface water quality to the standards of the Clean Water Act or to meet federal, state, or local laws and regulations standards and to create partnerships with other agencies to maximize resources and expertise to maintain or restore park water resources.

Southern Plains Inventory and Monitoring Network (SOPN) has identified two vital signs for monitoring and assessing surface water at Sand Creek Massacre National Historic Site: water quality and water quantity. Water quality will be used as an indicator for this resource topic, whereas water quantity will be addressed in the riparian habitat section of this NRCA. However, no formal water quality monitoring program has been implemented at the Historic Site to date.

Water has long been a scarce resource in the western and central portions of the



NPS - KARL ZIMMERMANN

Figure 4.6.1-1
Sand Creek runoff.

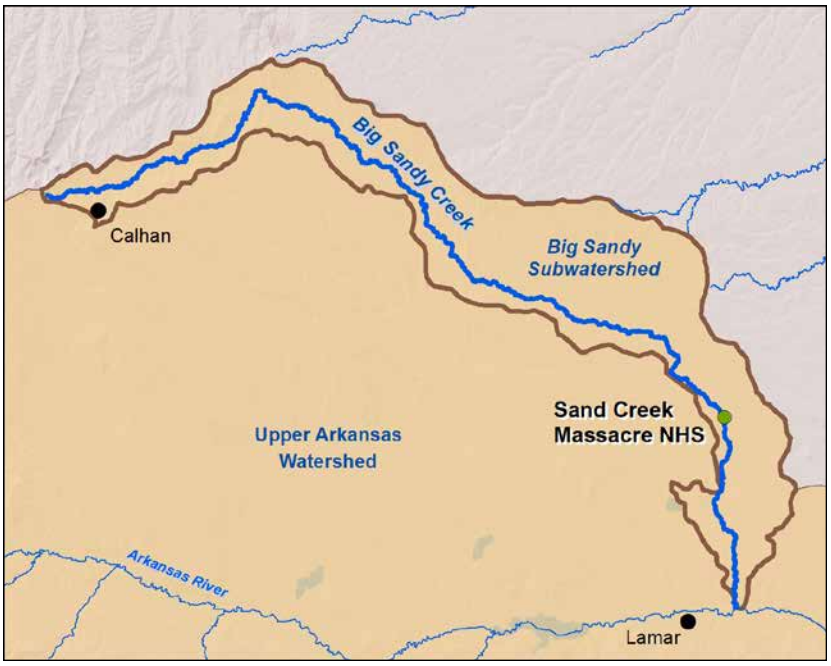


Figure 4.6.1-2 The Big Sandy subwatershed drains an area of 1,890 sqaure miles.

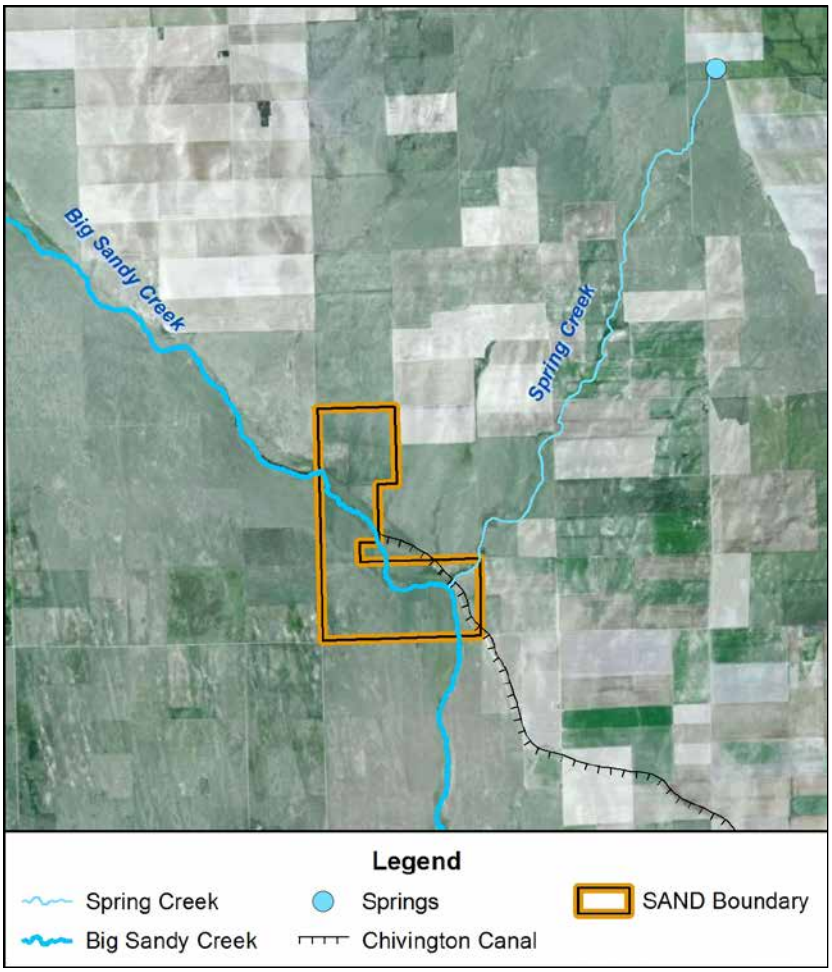


Figure 4.6.1-3 Major surface water features located within Sand Creek Massacre NHS boundary.

Great Plains and very important to Native Americans, early European settlers, and present day inhabitants and ecosystems (Perkins et al. 2005). Sand Creek Massacre NHS commemorates the attack on the Cheyenne and Arapaho camps that were located along Big Sandy Creek also known as Sand Creek. This is the park's major hydrologic feature and also its namesake.

Sand Creek originates near Calhan, Colorado and forms a confluence with the Arkansas River in Lamar, Colorado. It's an ephemeral stream that is 212 miles (341 km) long, with extensive stretches of dry areas, although it still maintains an underground water flow despite the dry stretches (Tilmant et al. 2006). Its watercourse drains a large watershed in excess of 1,890 square miles (Figure 4.6.1-2). Despite the relatively large size of the drainage it is unlikely that this watershed produces extreme flood conditions due to the permeable soils and the gentle drainage slope (Yost 2008). Approximately 3.25 miles (5.23 km) of Sand Creek is located within the Historic Site, containing both perennial and intermittent stretches of flow (Figure 4.6.1-3). Other hydrologic features at Sand Creek Massacre NHS include Spring Creek, which contributes to Sand Creek's surface water and the Historic Site's riparian habitat, and Kern Spring, which is a perennial flow that supplies surface water to Sand Creek's floodplain. In addition, a portion of the Chivington-Brandon Irrigation Canal (1.2 miles (1.9 km), which extends along the eastern edge of the Historic Site's floodplain, lies within the Historic Site's boundary and has an overall total length of 13.7 miles (22 km). All distances for the hydrographic features were derived using USGS hydrographic GIS data (2013) (Heidi Sosinski, e-mail correspondence, January 22, 2013).

4.6.2. Data and Methods

Water Quality

According to the U.S. Geological Survey Water Science School, water quality is "a measure of the suitability of water for a particular use based on selected physical, chemical, and biological characteristics" (USGS 2012). Surface water quality is

important to maintaining a healthy habitat for many aquatic organisms, wildlife, and humans and can provide insights into overall system productivity, can shift species abundances and distributions, and alter nutrient cycles (USDI NPS 2008).

Indicators/Measures

Water Quality (temperature, specific conductance, pH, dissolved oxygen, and turbidity)

Typically, parks containing water resources conduct surface water monitoring to determine the trends in core water physiochemistry. Core water quality parameters —temperature, specific conductance (the ability of a solution to conduct an electrical current, i.e., the lower the conductivity, the "purer" the water), turbidity, pH, and dissolved oxygen— reflect the function of the physical and biological environment with which water interacts. These indicators are easily measured and constitute a means of characterizing potential stressors to the health of aquatic systems. Monitoring for the parameters dovetails with that of the NPS service-wide Water Quality Monitoring Program, which requires each network to collect all of these parameters (except for turbidity) with any water quality monitoring effort (Gwilliam, in prep). Ideally, multiple water sampling throughout the water year obtains a better understanding of the range of conditions compared to episodic sampling, which captures information pertaining to that specific date and time only (Schweiger et al. 2012).

In addition, indicators including sediment physiochemistry, which measures the presence of nutrients, major ions, and metals, and bioassessments, which determine the presence and composition of biological communities, usually stream macroinvertebrates, are common indicators used to assess the condition of surface water bodies. Trace metal contaminants are sampled for in the water column as total suspended solids and in sediments deposited from the water column. Many metals bioconcentrate, leading to greater concentrations higher up the food chain.

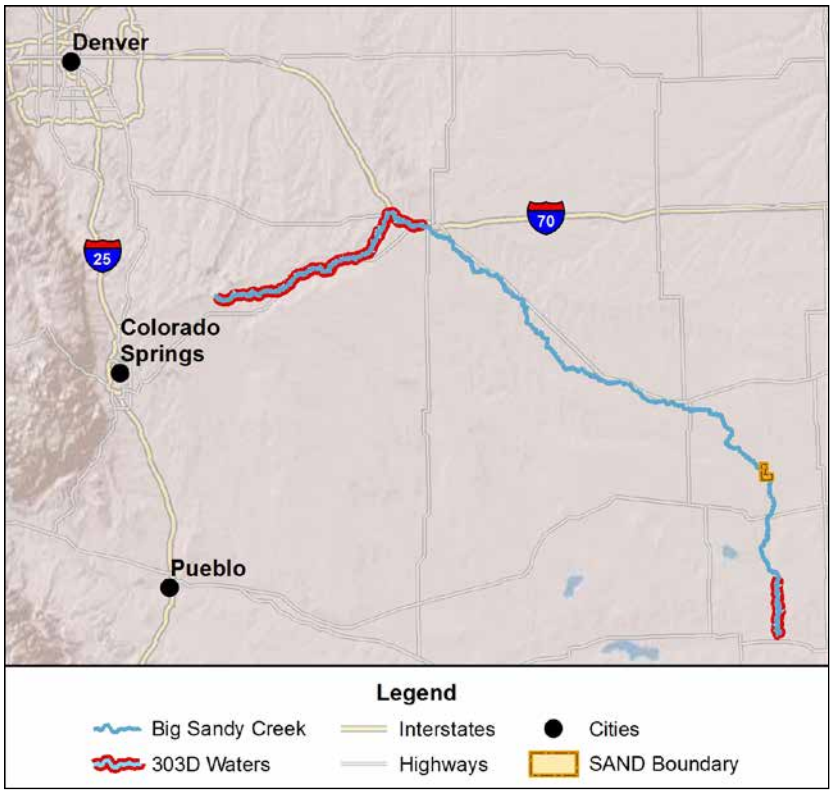


Figure 4.6.2-1 Stretches of Sand Creek listed on Colorado's 303(d) list of impaired waters due to high concentrations of selenium.

Water Quality Monitoring at the Historic Site

Unfortunately, no formal water quality monitoring program exists at Sand Creek Massacre NHS. The only surface water data collected for the park was from a limited (one day) fish inventory that occurred on March 14, 2006 at five pond locations along Sand Creek within the Historic Site. Water quality parameters of conductivity, temperature and salinity were recorded (Tilmant et al. 2006), but these data do not reveal anything relative to current water quality condition.

Instead, we searched water quality records from the U.S. Environmental Protection Agency's Water Body Reports for Big Sandy Creek. Even though direct sampling didn't occur at the Historic Site, the records indicated that Sand Creek's headwaters- a 61.1 miles stretch from Peyton to Limon, Colorado-are impaired for warm water aquatic life class 1 (state water standards) due to selenium. This had been reported for four report years since 2004 (EPA 2013a) (Figure 4.6.2-1).

In addition, a 13.5 mile stretch of Big Sandy, flowing south until joining the Arkansas River, is also impaired due to high selenium levels impacting warm water class 2, fish, shellfish, and wildlife protection and propagation. (EPA 2013b) (Figure 4.6.2-1).

4.6.3. Reference Conditions

The Colorado Department of Public Health and Environment Water Quality Control Commission establishes water quality standards for each Colorado river basin to maintain and improve the quality of the state surface waters (Colorado Department of Public Health and Environment Water Quality Control Commission 2012). The regulations are based upon the best available knowledge to insure suitability for public water supply, domestic, agricultural, industrial and recreational uses, and for the protection and propagation of terrestrial and aquatic life (Colorado Department of Public Health and Environment Water Quality Control Commission 2012). The water quality standards established for the Arkansas River Basin, which Big Sandy Creek is part of, are intended to be used in conjunction with Regulation No. 31 Basic Standards and Methodologies for Surface Water (Colorado Department of Public Health and Environment Water Quality Control Commission 2012). Big Sandy Creek is located within the Upper Arkansas Basin region and different stream segments are assigned different water quality values. Since we lack water quality data for the creek within the Historic Site, and water quality standards are subject to change, we did not develop any reference conditions for this resource topic

4.6.4. Condition and Trend

Sand Creek Massacre NHS does not currently have a monitoring program in place to gather baseline water quality data so no park specific information was used for this assessment. As a result, resource condition could not be assessed. However, we can discuss threats to the Historic Site's water quality in general terms.

Most of the flow of Big Sandy Creek is subterranean except during heavy rainfall events or where the surface features allow a permanent surface flow over short distances. (Tilamnt et al. 2006). The intermittent flow of Sand Creek makes it difficult to establish baseline information on a frequently consistent basis.

We did however discover that toxic levels of selenium were recorded both upstream and downstream from the Historic Site, with both segments listed on Colorado's 303(d) list of impaired waters (Figure 4.6.2-1). Under section 303(d) of the Clean Water Act, states are required to develop lists of impaired waters that are too polluted or otherwise degraded to meet the established water quality standards. The law requires that states establish priority rankings for waters on the lists and develop a Total Maximum Daily Load for these waters, which is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards (EPA 2012a).

Selenium in water bodies have been mostly related to irrigation of western soils that are naturally high in selenium, ash pond discharges from coal-fired power plants using coal that has selenium in it, petroleum refinery effluents, and runoff or discharges from certain mining activities (EPA 2012b) but is also a naturally occurring phenomenon along Colorado's front range (Fran Pannebaker, pers. comm. July 24, 2013). Selenium naturally occurs as an element (metal) that is nutritionally essential, but it can be toxic to aquatic life (such as fish and invertebrates) where concentrations are excessive. Selenium is a bioaccumulative pollutant, and risks stem from aquatic life eating food that is contaminated with selenium rather than from direct exposure to selenium in the water. For aquatic life, the toxic effects with the lowest thresholds are effects on the growth and survival of juvenile fish and effects on larval offspring of the adult fish that were exposed to excessive selenium. In the latter case, besides reducing survival, selenium causes skeletal deformities. The EPA is proposing a revision to the water quality criteria for selenium. All concentrations are in μg/L except the tissue criterion, which is in μg/g and the proposed level of selenium in freshwater systems is

258 / 417 formula (acute) and 7.9 for tissue (chronic) (EPA 2012c).

According to USDI NPS (2008), stream flow data have been collected by the Town of Eads Public Works Division from 2003 to at least 2008 (USDI NPS 2008). SOPN's Phase III Monitoring Plan (USDI 2008) identified these data as a potential source of information for the Historic Site and they may be worth assessing if a surface water monitoring program is ever implemented at the park.

Level of Confidence/Key Uncertainties/ Threats

The level of confidence assessment is irrelevant due to the lack of specific surface water quality data. In general though, water quality throughout the Great Plains has been affected by herbicides and other pollutants, and SOPN park water resources are no exception to these threats (Perkins et al. 2005).

Agricultural use of nitrogen fertilizers is the largest source of nitrates in near-surface aquifers in the midcontinent (Koplin et al. 1994). For example, over 100,000 metric tons of pesticides (herbicides, insecticides, and fungicides) were applied in the midcontinent in 1991, often to control nonindigenous plants and animals. Effects of these pollutants on the quality of human life and on the integrity of the ecological community are largely unknown. The U.S. Environmental Protection Agency has initiated an effort to develop stressor information to help recognize areas where urban development, agricultural nonpoint pollution (pesticides, toxic chemicals, nutrient pollution), and agricultural development may exacerbate ecological decline. So for example, with high selenium levels above and below the Historic Site, monitoring for this metal may be a high priority within the scope of a surface water monitoring program. In addition, due to the Historic Site's geographic position, the main surface water concern is contamination from agricultural runoff.

Another threat is the significant changes in the amount and permanency of surface and groundwater since pre-Columbian times as a result of ranching (e.g., stock ponds), irrigation, flood control, and other anthropogenic changes. Few major rivers in the Great Plains still exhibit the conditions evident before agricultural development and water management had occurred. Altered river hydrographs from dams, irrigation and municipal withdrawals, groundwater depletion, and other land use changes are a significant impact to aquatic systems in the Great Plains (Cross and Moss 1987, Longo and Yoskowitz 2002). According to Martin et al. (2012), future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table, which in turn would affect the amount of water in the creek. In addition, the region encompassing the Historic Site is currently under drought conditions, exacerbating water quality issues.

4.6.5. Sources of Expertise

No experts were consulted due to the limited information pertaining to surface water quality and quantity at Sand Creek Massacre NHS.

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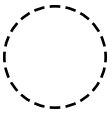
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4.7. Groundwater

Indicators/Measures

- Change in Groundwater Level

Condition – Trend - Confidence



Insufficient Data - Insufficient Data - Low

4.7.1. Background and Importance

Groundwater accounts for 1.7% of Earth's total water and 30.1% of Earth's freshwater (USGS 2011a). The overall trend in the United States is that as population increases, the amount of groundwater withdrawn also increases (Figure 4.7.1-1).

Long-term water-level declines caused by sustained groundwater pumping are a key issue associated with groundwater use, and many areas of the United States are experiencing groundwater depletion. Groundwater resources supply approximately 18% of Colorado's water supply needs (Colorado Geological Survey 2013a). With streams being sparse throughout Colorado's eastern plains, groundwater use is higher compared to surface water withdrawals. Groundwater withdrawal accounts for nearly 100% of use in Kiowa County (Colorado Geological Survey 2013a).

One environmental consequence to groundwater depletion is land subsidence, which is the settling or sinking of the Earth's surface. The increasing development of land and water resources threatens to exacerbate existing land-subsidence problems and initiate new ones throughout the United States (USGS 2011b).

NPS Management Policy 4.6.1 states that the NPS will perpetuate surface waters and groundwaters as integral components of park aquatic and terrestrial ecosystems (NPS 2006). It is the policy of the NPS to determine the quality of park surface and groundwater resources and avoid, whenever possible, the pollution of park waters by human activities occurring within and outside of parks.

Aquifer Characteristics

Most of the Sand Creek Massacre NHS area is covered by a thin layer of Quaternary deposits that are made up of sand, gravel, silt, and clay deposited by wind and streams (Martin 2006). These deposits are made up of three groups: terrace deposits that are higher than the stream level (primarily east of Big Sandy Creek); dune sand (primarily west of Big Sandy Creek); and valley-fill deposits along streams. The layer, which is permeable, is a

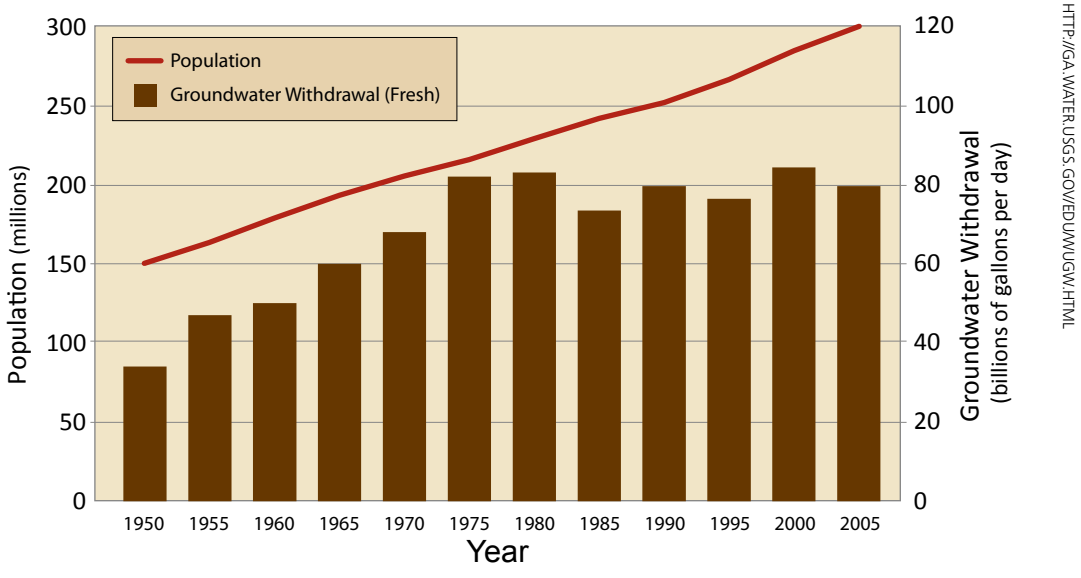


Figure 4.7.1-1. Groundwater withdrawals for the United States, 1950–2005.

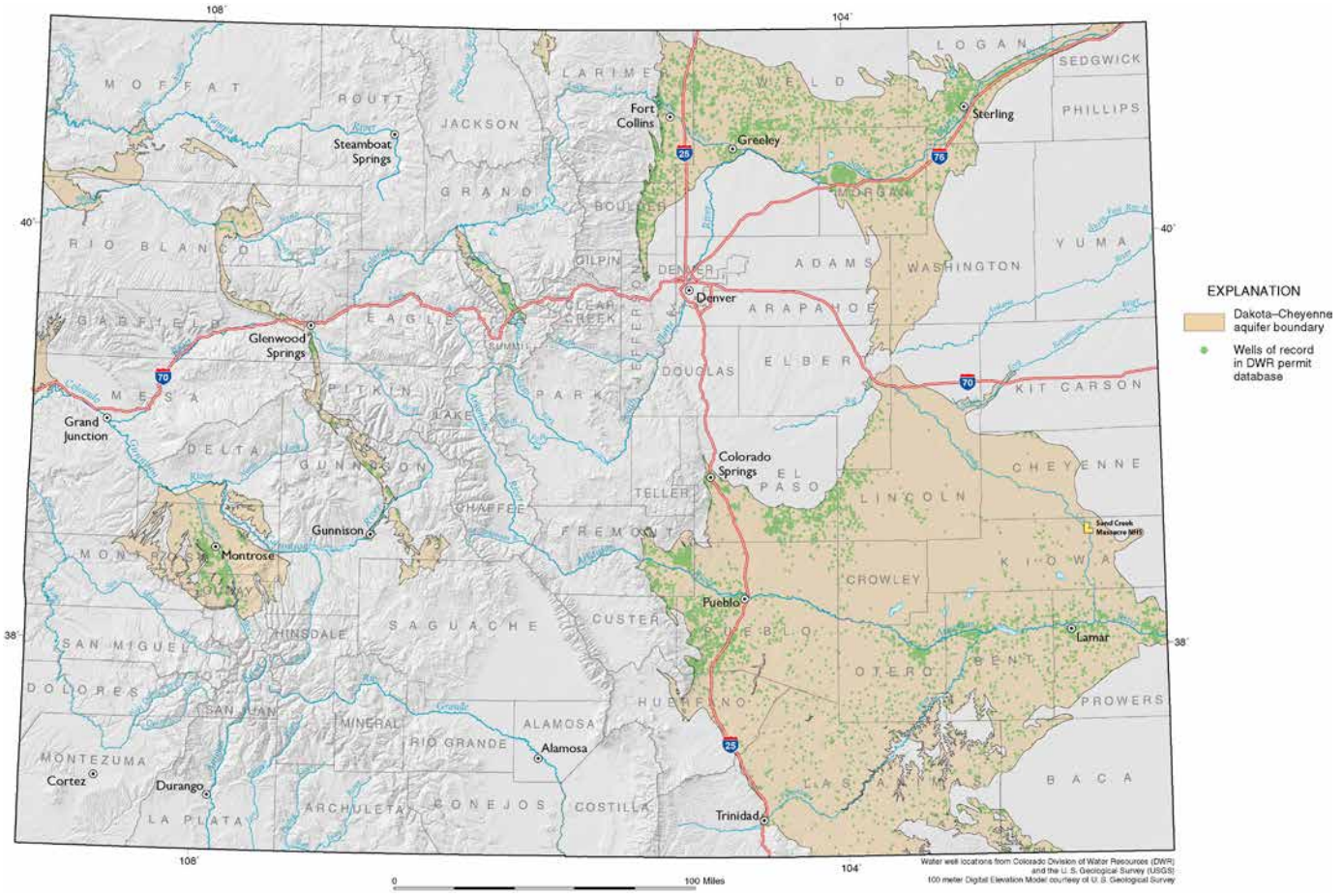


Figure 4.7.1-2. Occurrence of the Dakota-Cheyenne Aquifer (yellow-brown shading), outside of designated basins and the High Plains aquifer, in Colorado.

few tens of feet thick. Beneath the Quaternary deposits are rocks from the Late Cretaceous period, approximately 80-85 million years old. The Cretaceous bedrock formations, several thousand feet thick, are relatively impermeable and generally pose a barrier to the downward movement of groundwater. Rainfall infiltrates the permeable Quaternary deposits and accumulates above the Cretaceous formations, forming a shallow, perched aquifer. Groundwater in the Quaternary formations is recharged by rainfall.

Below the shallow aquifer just described, the next potential source of groundwater is the Dakota Sandstone, which is about 1,000 feet below the ground surface (Martin 2006). This layer is a component of the Cretaceous bedrock formations, which are primarily shale but contain some limestone beds (Martin 2006). Although only one well was known to exist in the Dakota Sandstone in the county in 1979 (Mustard and Cain 1981), other deep wells were constructed since then (Martin 2006).

The Dakota-Cheyenne Group is an assemblage of sandstones, shales, and mudstones that occurs throughout most of the state; it is an important aquifer in many areas (Figure 4.7.1-2) (Colorado Geological Survey 2013b). It is difficult to characterize the aquifer because of its complexity and extent in the state (Colorado Geological Survey 2013b). The database of the Colorado Division of Water Resources lists more than 27,500 potential wells of record in the aquifer, with those in the general vicinity of Sand Creek Massacre NHS shown in Figure 4.7.1-3 (Colorado Geological Survey 2013b). In southeastern Colorado, the water from the aquifer is used mainly for irrigation purposes and domestic water supply.

Groundwater Wells

A 2006 report examined the potential groundwater sources for a potable water supply for the visitor center and administrative

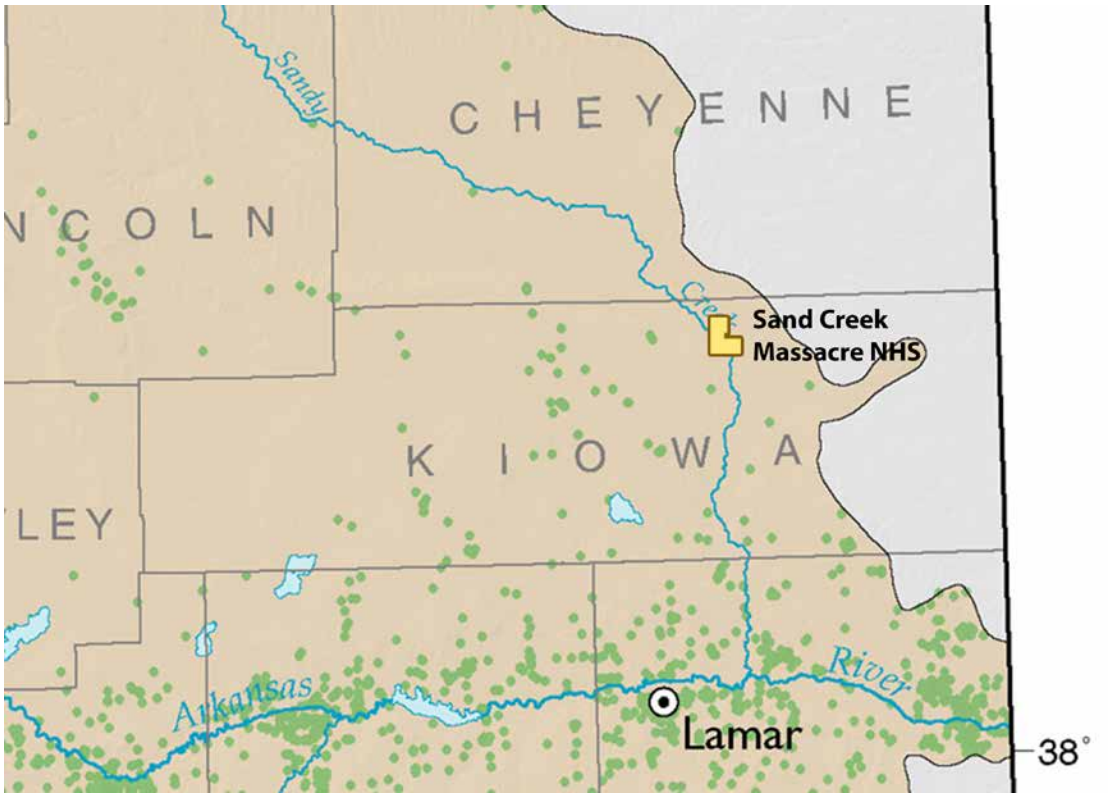


Figure 4.7.1-3. The Dakota-Cheyenne aquifer (yellow-brown shading) in the vicinity of Sand Creek Massacre NHS, and wells permitted by the Division of Water Resources (green dots). Source: Figure 6.8-1, Colorado Geological Survey 2013b).

site for the Historic Site (Martin 2006). Martin (2006) reported that the Dakota Sandstone was at a depth of about 1,000 feet and probably contained poor water quality. Therefore, he recommended that groundwater in the shallow aquifer in the Quaternary deposits (in valley-fill deposits) be used for potable water at the Historic Site. Three shallow wells were present at the Historic Site, one for former domestic supply, irrigation, and livestock (Alexa Roberts, Sand Creek Massacre NHS, pers. comm.).

The 2006 Martin report also pointed out there were some old wells at the site that may not have had adequate surface seals to prevent the flow of surface water down the outside of the wells; this could lead to contaminants reaching the aquifer. Since the report, the wells were inspected and redrilled/updated, and they are now monitored by the state (Karl Zimmermann, pers. comm.).

The NPS Water Resources Division installed twleve water level monitoring wells along the ponds along Big Sandy Creek within the Historic Site (Karl Zimmermann, pers. comm., Kevin Noon, NPS, pers. comm.). Eight wells were installed in 2007 and four were installed in 2011. Six of the wells have automated readers that were installed by Kevin Noon and monitored by Historic Site staff. In 2013, the lowest groundwater elevation levels were recorded. The data from the wells will be used for baseline and long-term monitoring.

4.7.2. Data and Methods

Since groundwater storage is determined by aquifer characteristics and water levels within the aquifer, changes in storage are directly associated with changes in water levels. Rising water levels indicate increased storage resulting from greater inflow than outflow, while declining water levels indicate that outflow exceeds inflow. Thus, change in groundwater level can be used as an indicator of groundwater condition.

However, a search of the U.S. Environmental Protection Agency's STORET database lead to no data available on groundwater monitoring wells in Kiowa and Cheyenne counties (conducted February 2013). Although, as mentioned above, the NPS installed twelve monitoring wells along Big Sandy Creek, data are not yet available. Even if data from the twelve wells had been available, it would only have been for a very short period of

Table 4.7.4-1. Summary of the groundwater indicator/measure and its contribution to the overall groundwater natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Change in groundwater level	Water level can indicate depletion of an aquifer if the level continues to lower. This can be a result of supply exceeding demand and/or from a recharge rate that cannot maintain a degree of sustainability for the aquifer. On the other hand, if water level increase occurs that may be a result of retired wells and/or from recharge rates exceeding extraction.	We were unable to conduct an assessment of groundwater resources at Sand Creek Massacre NHS due to a lack of data.

time. Additionally, Martin (2006) presented monitoring data from 1959-1986 collected by USGS from a shallow well at the Dawson property. These data indicated that water levels were from about 5-7 feet below ground surface, with no significant trend over the 30-yr period. No additional, recent data, however, are available.

Because no groundwater level data are available, no assessment was made for the status and trends of groundwater resources in Sand Creek Massacre NHS at this time.

4.7.3. Reference Conditions

The reference condition we used for change in groundwater level is one of sustainability; where on average, supply meets demand. When supply meets demand, we expect variability that reflects annual variation in environmental conditions (e.g., rainfall, evapotranspiration, pumping), but lacks an overall long-term declining water level trend.

4.7.4. Condition and Trend

Because no data on groundwater levels are available, no assessment was made for the status and trends of groundwater resources in Sand Creek Massacre NHS at this time. The twelve monitoring wells installed by NPS in 2011 will provide a foundation for future monitoring and assessment.

Overall Condition/Trend

For assessing the condition of groundwater, we used one indicator/measure, which is summarized in Table 4.7.4-1. However, based on a lack of groundwater data at this time, we cannot make conclusions on the condition and trend of groundwater resources at the Historic Site.

Key Uncertainties

Very few data were available for this assessment. Additionally, we do not know the current supply and demand for groundwater in this area and cannot predict future development throughout the area.

4.7.5. Sources of Expertise

This brief assessment was based on the report by Martin (2006), personal communications with NPS staff about the recently installed groundwater monitoring wells, and online resources of the Colorado Geological Survey.

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4.8. Riparian Habitat

Indicators/Measures

- Hydrology (5 indicators)
- Vegetation (7 indicators)
- Erosion/Deposition (5 indicators)

Condition – Trend– Confidence



Good - Insufficient Data - High

4.8.1. Background and Importance

Riparian wetlands are a type of non-tidal wetland formed along river and stream floodplains. These wetlands serve many functions including water purification, flood control, buffering riverbank erosion, habitat for numerous wildlife, fish, shellfish, and plant species, and also provide many recreational opportunities. In the arid west, riparian habitat is often in marked contrast with the surrounding terrestrial vegetation and is strongly influenced by the presence or absence of water (NPS-WRD 2011).

The National Park Service (NPS) has several wetland protection procedures and policies (Director's Order #77-1: Wetland Protection (2002), Procedural Manual #77-1 (2012), Director's Order #77-2: Floodplain Management and Procedural Manual (2003) and NPS Management Policies (2006a)) to ensure a "no net loss" of wetlands throughout the NPS.

Setting (*Excerpted from Martin et al. 2012*)

The entire Big Sandy Creek drainage basin is about 1,890 square miles beginning in the vicinity of Calhan, Colorado and continuing predominantly southeast until forming a confluence with the Arkansas River about eight miles east of Lamar, Colorado. The major tributaries of Big Sandy Creek are Rush, Wild Horse, and Big Spring Creeks, the largest being Rush Creek.

As the name implies, Big Sandy Creek, also known as Sand Creek, is an alluvial stream, meaning that its bed and banks are composed of sediment recently transported (in a geologic sense) by the watercourse. The valley that Sand Creek occupies has been carved out of Cretaceous bedrock formations, namely the Pierre Shale, the Niobrara formation, and the Carlile Shale. These predominantly marine deposits are very thick (upwards of 4000 feet) and are also relatively impermeable. Consequently, the bedrock formations underlying the valley-fill alluvium serve as confining layers, prohibiting downward movement of soil water and groundwater, and supporting water table conditions in the overlying Quaternary sediments.

The valley fill sediments associated with Big Sandy Creek are composed of different particle sizes ranging from gravel to clay, mostly deposited by flowing water (alluvium) but also with some wind deposition (eolian), especially on the surface. The average thickness of the valley fill is about seven to nine meters with a range that varies from 0 to about 20 meters. The areas of thickest



Figure 4.8.1-1. Sand Creek is a tributary of the Arkansas River and part of the Upper Arkansas watershed.

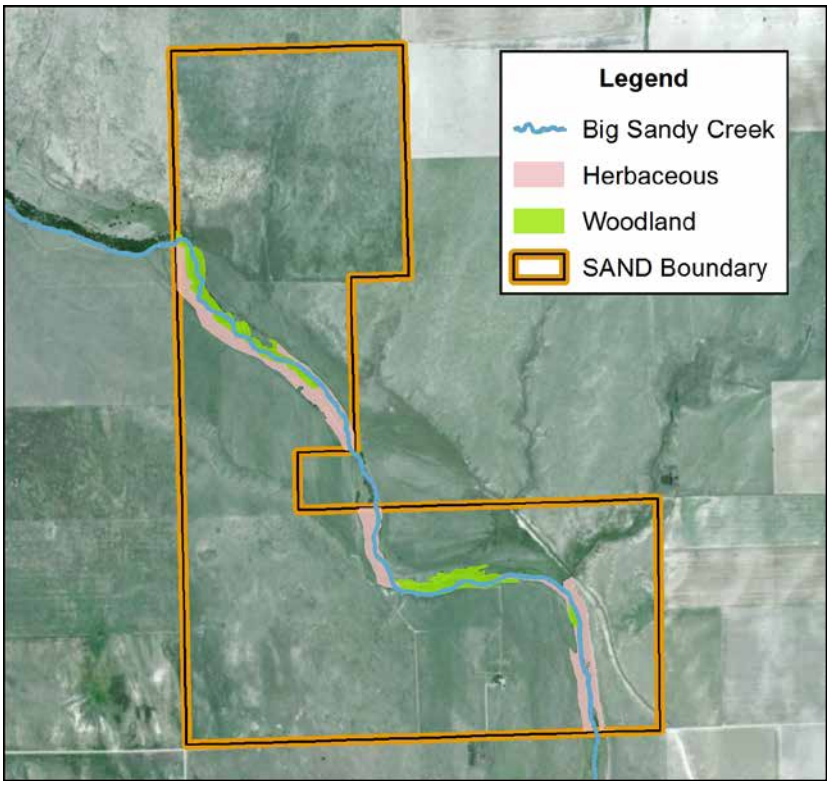


Figure 4.8.1-2. Riparian habitat within the Historic Site located along Sand Creek.

deposition are generally in the approximate center of the valley.

Geomorphic History (*excerpted from Martin et al. 2012*)

The overall configuration of the creek is a meandering alluvial channel underfit in its broad valley. Competent flows, those capable of transporting sediment and re-working the channel, are rare and occur roughly every five to ten years. As a result of this infrequency of "channel forming flows," Big Sandy Creek channel is poorly defined throughout most of the Historic Site. The geomorphic features that are generally associated with meandering streams (such as point bars, cutbanks, and overflow channels, to name a few) are largely absent or poorly formed. Quaternary fluvial terraces, however, are both well formed and well preserved, throughout the area.

At least four fluvial terraces levels in addition to the modern floodplain exist within the watershed of Big Sandy Creek (Coffin and Horr, 1967). A focused study aimed at identifying likely locations of in-situ cultural material in the vicinity of Sand Creek Massacre identified the presence of three distinct terrace levels (in addition to the modern floodplain level) throughout the Historic Site (Holmes and Mcfaul, 1999).

The floodplain level, referred to as the "modern floodplain" lies very near the elevation of the active stream channel, at places where a channel has formed, and for the most part, has a surface that is fairly smooth with some evidence of recent flow. The width of the modern floodplain varies from about 150 to less than 300 meters and is bounded by fluvial terraces of older age sediments, thick eolien deposits, or bedrock cliffs at some locations. Very weak soil development on the surface of the floodplain implies a very young landform consistent with a floodplain and active stream channel system.

The next oldest fluvial landform has been referred to as terrace level. This landform bounds the modern floodplain through most of the Historic Site, at least where it has not been removed by erosion. The surface of this terrace level is only about 0.5 meters above the floodplain level and is often difficult to distinguish. The alluvial material is predominantly coarse grained sand but may be covered with as much as 10 cm of medium grained, well sorted, eolian sands. This mantle of wind derived sediment is discontinuous, variable in thickness, and may obscure boundaries between older landforms. Although at least two other terrace levels are evident within the Historic Site this riparian assessment is only concerned with the modern floodplain and portions of the lowest fluvial terrace where it supports riparian vegetation.

Sand Creek runs approximately 3.25 miles (5.23 km) within the Historic Site and the riparian habitat is comprised of woody species, predominately Plains cottonwood (*Populus deltoides*) and herbaceous vegetation and occupies approximately 149 acres (60.4 hectares) (Heidi Sosinski, data manager, Southern Plains I&M Network, personal communication, February, 2013) (Figure 4.8.1-2).

A properly functioning riparian habitat is influenced by several factors and interactions between geologic formations, soil, water, vegetation, and local as well as regional (watershed) land use activities/practices. A river system and associated riparian habitat is always attempting to maintain a dynamic equilibrium between streamflow forces and channel processes. A naturally functioning system is able to respond to larger waterflow events without excessive change to the riparian habitat plant communities and river channel characteristics. In fact, these larger flow events are a necessary process in the evolution of a river and riparian system, and as a result, aquatic and riparian habitat is maintained and water quality is enhanced. It is when ongoing impacts to the natural river processes occur that riparian habitats can no longer maintain resiliency and proper functioning.

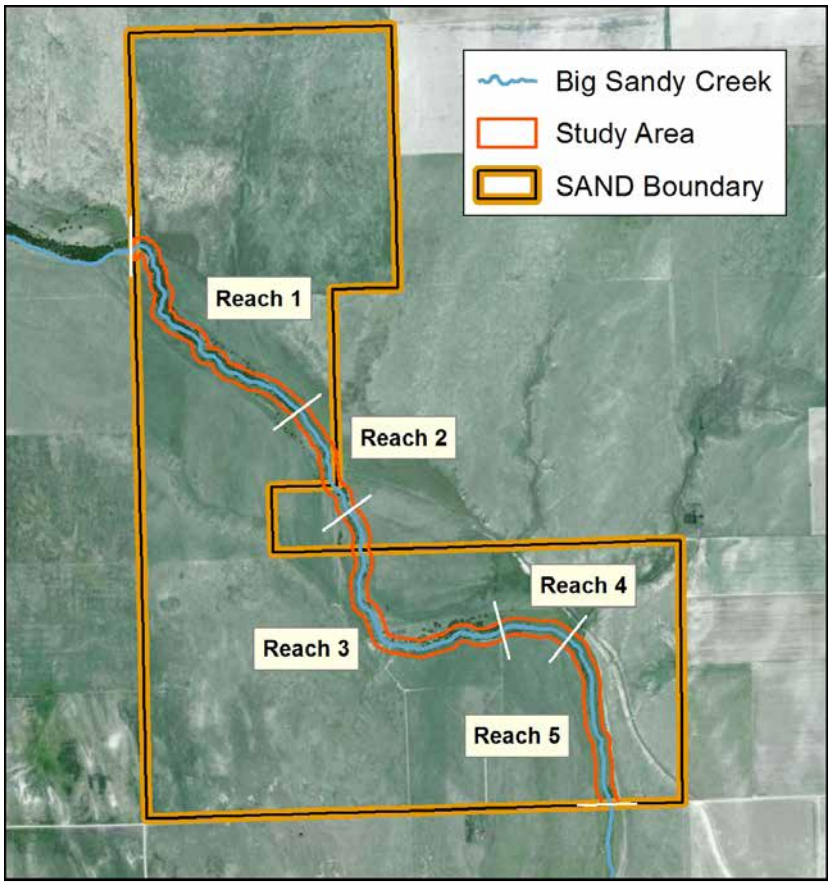


Figure 4.8.2-1. Sand Creek was divided into five separate reaches for the assessment.

4.8.2. Data and Methods

An interdisciplinary team of experts from NPS' Water Resources Division and Southern Plains Inventory and Monitoring Network conducted a qualitative riparian habitat assessment at the Historic Site (Martin et al. 2012) using "A User Guide to Assessing the Proper Functioning Condition and the Supporting Science for Lotic Areas" developed by Prichard et al. (1998). Their assessment methodology was based upon a "Proper Functioning Condition (PFC)", which describes both the condition assessment process as well as a reference condition (Prichard et al. 1998). They divided Sand Creek into five segments for evaluation based on the degree of channelization and the structure of the associated cottonwood galleries throughout these five segments (Martin et al. 2012) (Figure 4.8.2-1). Readers seeking additional details of Martin et al. (2012) Proper Functioning Condition Assessment of Big Sandy Creek are encouraged to download it from (http://www.nature.nps.gov/publications/nrpm/nrr.cfm).

Both terrestrial and aquatic attributes and processes are important in riparian habitat areas and are used to assess the condition of a given area. This assessment included three main categories including hydrology, vegetation, and erosion/deposition. A total of 17 common attributes and processes within each of these three categories was assessed by the interdisciplinary team (Figure 4.8.2-2) using a standardized checklist/datasheet developed by Prichard et al (1998). It is the culmination of these indicators, listed below, that determined the overall condition of the Historic Site's riparian habitat.

Indicators/Measures

Hydrology

Streamflow forces and channel processes are characteristics of a riparian habitat's hydrologic function, and five attributes/processes were assessed for this category of measure.

Indicator: Floodplain inundated frequently

A floodplain is topographically flat, a landform of unconsolidated sediments originating from the stream, and subject to periodic flooding,



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Figure 4.8.2-2. Plains cottonwoods along Sand Creek.

usually a recurrence interval between 1 and 3 years (Prichard et al. 1998). The floodplain's role is to handle a basin's discharge and sediment load by spreading out the water and sediment onto a low area adjacent to the stream. This hydrologic function dissipates energy, which keeps a riparian habitat in functioning condition. Periodic flooding also promotes vegetation growth, which contributes to a properly functioning riparian area as well.

Indicator: Beaver dams are active and stable

Beaver dams modify the hydrology of the area where constructed, and in some areas are responsible for the creation of floodplains (Gebhardt et al. 1998). However, sometimes when dams are not maintained, they can breach and instantaneously release a massive amount water potentially causing degradation to the riparian system.

Indicator: Sinuosity, width/depth ratio, and gradient are in balance

Stream channel characteristics play an important role in how well the river system can dissipate energy. A higher stream gradient or a decrease in sinuosity will increase velocity resulting in accelerated erosion. To achieve balance, the size and shape of a stream should be near what would be expected within the setting it occupies.

Indicator: Riparian habitat area is widening or has achieved potential extent

Sediment capture develops floodplains, which in turn, aids functionality of a riparian habitat area. In addition, as sediment is deposited, vegetation can "take root", increasing certain types of vegetation such as sedges, willows, and rushes.

Indicator: Upland watershed is not contributing to riparian habitat degradation

Assessing changes in water and/or sediment supply from uplands can help determine functionality of the riparian habitat area affected. Changes in upland conditions can affect the discharge, timing, and duration of streamflow events in lower areas, possibly degrading a riparian habitat's condition.

Indicators/Measures

Vegetation

Most riparian habitats require some amount of vegetation to achieve functionality (Prichard et al. 1998). Different factors such as type, amount, and proportion of vegetation contribute to a riparian habitat's condition. In order to accommodate periodic flooding, lateral distribution of vegetation is necessary. In addition, plants must be vigorous and

able to maintain or recruit into the plant community to serve their various functions.

Indicator: There is a diverse age-class distribution of riparian habitat vegetation

Age class distribution is often associated with vigor of a system, and multiple age classes of vegetation provide recruitment and replacement. Not all age classes need to be present for a system to maintain or recover from a severe event, and the older age classes can usually persist even with degraded conditions.

Indicator: There is diverse composition of riparian habitat vegetation

Not all plants need to be present within a riparian habitat for the system to maintain itself, but there needs to be enough variety for a riparian habitat to recover and maintain its vegetative component. Limited number of species makes an area more vulnerable to extreme climatic changes or disease, although areas that contain unique water regimes or soils may naturally only support a limited number of plant species.

Indicator: Species present indicate maintenance of riparian habitat soil moisture characteristics

Plants that grow in riparian habitats are hydrophytes and must be in contact with the water table in order to survive. Different types of plants require different wetness regimes and different plants vary in root depths. The root depths sometimes suggest that a water table may not be close to the surface if the plants growing are ones that usually have deeper root systems. Riparian plants are divided into different categories, indicating their preference for growing in wetlands or uplands and degree of wetness required.

Indicator: Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events

Plants that have adapted to riparian habitat conditions, such as cottonwood, aspen, alder, willow, sedge, rush, and some grasses, develop root masses that help stabilize riverbanks, especially during high-flow events. If banks are undercut during storm or high runoff events, many changes can occur to the channel's width/depth ratio, gradient, and sinuosity, which in turn, may decrease the system's ability to dissipate energy. The presence of obligate and facultative wetland plants is usually a good indication that the streambank will remain stabilized.

Indicator: Riparian habitat plants exhibit high vigor

If plants are weakened or stressed, they are less able to withstand stressors making the riparian habitat more susceptible to degradation. On the other hand, plants that exhibit vigor are usually more equipped to maintain or recover from stressors.

Indicator: Adequate riparian habitat vegetation cover is present to protect banks and dissipate energy during high flows

The amount of vegetation present indicates a riparian habitat's ability to dissipate energy, protect riverbanks from collapse, filter sediment, and aid floodplain development, which also dissipates energy during storms or high runoff. Some bank erosion is a natural part of river channel evolution, but excessive erosion usually indicates some failure in the system.

Indicator: Plant communities are source of large woody material (for maintenance/ recovery)

Not all areas support large woody vegetation and many rangeland and meadow riparian habitat areas do not require woody species to maintain channel stability. However, if this type of vegetation is a natural part of the system, it serves as a hydrologic modifier. Usually, during high-flow events, coarse or woody vegetation must be present to withstand the high energy and to recover the system back to a proper functioning condition.

Indicators/Measures

Erosion/Deposition

Erosion and depositional processes are naturally occurring within a stream or river system, however, excessive amounts of either

indicate an imbalance in the system. Five indicators were used to assess the erosion/deposition processes for this assessment.

Indicator: Floodplain and channel characteristics are adequate to dissipate energy

Energy dissipation results from the presence of a floodplain, which distributes the water over a larger area, and channel characteristics such as sinuosity, which reduces the velocity of waterflow. In addition, objects such as rocks or large woody debris can also aid in energy dissipation.

Indicator: Point bars are revegetating

In some channels, point bars form as part of the natural depositional process and subsequent vegetation colonization aids in erosion control when high runoff events occur. The vegetative type has to be ones that are capable of forming root masses that can withstand high flow occurrences.

Indicator: Lateral stream movement is associated with natural sinuosity

Streams naturally adjust their channel by moving side to side without degrading the overall riparian habitat environment. The movement is affected by many factors such as the type of stream, the type of materials that form the streambanks, and the types and amounts of vegetation growing along the banks. For example, streambanks composed of sandy materials will more easily erode than materials such as clay or silt, which provide more cohesiveness. Excessive movement can negatively impact a river/riparian area by diminishing the system's ability to dissipate energy.

Indicator: System is vertically stable

This measure is used to determine whether a channel is lowering at a natural versus an accelerated rate. Naturally occurring channel lowering usually occurs over hundreds or more years, whereas, some accelerated lowering can occur over a decade or less. The channel lowering reduces the landscape's overall elevation including the valley bottom through erosion.

Indicator: Stream is in balance with the water and sediment being supplied by the watershed

Stream channels adjust to water and sediment loads and are classified as either single thread or braided channels. Most braided channels indicate unnaturally high sediment loads, whereas, excessive erosion indicates an imbalance in water flow.

4.8.3. Reference Conditions

A riparian habitat area needs to be in dynamic equilibrium with its streamflow forces and channel processes to be considered in proper functioning condition. This requires the system to maintain itself and/or recover after large runoff events without significant changes to the stream channel characteristics or to the riparian habitat vegetative communities (Martin et al. 2012). However, some change is expected and even necessary to maintain resiliency. In contrast, systems that are functional but susceptible to degradation due to failure in one or more of the attributes associated with either the hydrology, vegetation, or erosion/depositional processes are considered to be in moderate condition. Those systems that are not providing adequate functioning and subsequent protection are considered nonfunctional. These three states: proper function, functional-at risk, and nonfunctional, comprise the reference conditions against which the Historic Site's riparian habitat was assessed and is based on the condition definitions developed by Prichard et al. (1998) (Table 4.8.3-1). Prichard et al. (1998) also included a fourth condition class-Unknown- when sufficient information was unavailable to make a condition determination, however, this class was not applicable to the Historic Site's assessment therefore was excluded.

4.8.4. Condition and Trend

Overall Condition and Trend

The results for the Historic Site's riparian habitat condition assessment revealed that all five reaches during the 2012 assessment were considered to be in proper functioning condition, and no trend was identified. These results are listed in Table 4.8.4-1. Many of the

Table 4.8.3-1. The reference conditions used to determine whether the condition of the riparian wetlands at Sand Creek Massacre NHS is good, moderate, or of significant concern as adapted from Prichard et al. 1998.

Good	Moderate	Significant Concern
A good condition is referred to as a Proper Functioning Condition or PFC. PFC is a state of resiliency that allows a riparian wetland area to hold together during high flow events with a high degree of reliability. The resiliency allows an area to establish vegetative communities that create the structure necessary for fish and waterfowl habitat, to establish floodplains that help dissipate energy, and channel characteristics such as sinuosity and lower gradients, which help prevent streambank erosion.	A moderate concern condition is considered to be "Functional-At Risk" , which means that the riparian wetland area is in fundamental condition, but an existing soil, water, or vegetation indicator(s) is compromised making it susceptible to degradation. However, the majority of the riparian wetland indicators do not need to be compromised to receive a moderate condition rating.	A significant concern condition is considered to be "Nonfunctional". The riparian wetland area is not providing adequate vegetation, landform, or large woody debris to dissipate stream energy associated with high flows, therefore, erosion is not reduced and water quality degradation is occurring. In addition, channel characteristics are such that high flow events either deposit an inordinate amount of sediment or water flow results in excessive erosion.

results were common between all five reaches and are summarized below.

Hydrology Condition (*Excerpted from Martin et al. 2012)*

The Big Sandy Creek watershed is located in a semi-arid portion of the country where annual potential evapotranspiration greatly exceeds annual precipitation. Almost all of Big Sandy Creek flows only in response to substantial rainfall events; however, there are a few reaches that support perennial flow due to higher water table conditions. One such reach is within the Historic Site near the downstream end where spring flow from the east helps to maintain a higher water table and perennial surface water. The rest of Big Sandy Creek within the Historic Site is an ephemeral watercourse that only flows in response to precipitation.

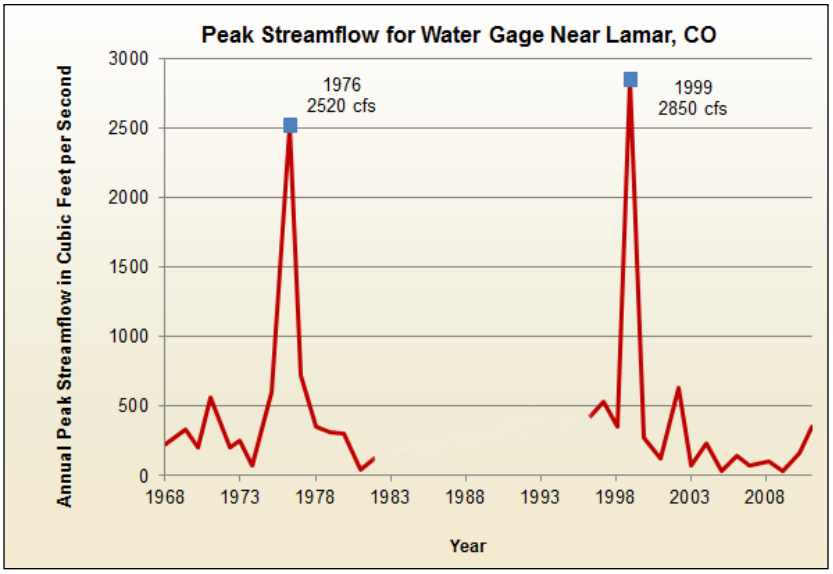


Figure 4.8.4-1 Peak streamflow at USGS water gage located just upstream from the confluence with the Arkansas River near Lamar., Colorado (USGS 2012).

About 48 kilometers downstream from the Historic Site, the USGS (2012) has operated a gage at Lamar, Colorado (#07133000) on a perennial reach of the stream for 32 years over a 45 year period, starting in 1968 and continuing to the present with a number of missing years from 1983 -1995. The range of annual peak flows recorded by this gage at Lamar is generally from about 100 to 500 cubic feet per second (CFS), with an occasional peak around 500-600 CFS. For comparison, regional flood frequency equations developed for Eastern Colorado suggest that an "average" watershed of this size should have an annual peak in the range of about 1700 cfs (Ries and Crouse, 2002). Consequently, BSC appears to be much less active hydrologically than other streams in this region. Only twice in the 30-year record did peak flow at the gage exceed the modest discharge value of 700 cfs, once in 1976, and again in1999. Both of these events were large and exceeded 2000 CFS.

On the other end of the flow distribution, daily discharge minimums have generally been below 10 CFS throughout most of the record, and even daily mean maximums are usually below 100 CFS. These relatively low flow values are generated from a contributing area that exceeds 2000 square miles further suggesting that this watershed is relatively "inactive." This is not to say that large flow events do not occur –they do, but they are

Table 4.8.4-1. Results for the riparian habitat condition assessment at Sand Creek Massacre NHS (Martin et al. 2012).

Indicator/ Measure	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Hydrology					
Floodplain	Relatively recent flood debris above banks and observations by Historic Site staff indicate stream is flowing and flooding lower terraces at its potential frequency.	Observed relatively recent flood wrack above channel banks, so floodplain is still inundated in relatively frequent events, though somewhat less so than in other reaches.	Relatively recent flood debris above banks and observations by Historic Site staff indicate stream is flowing and flooding lower terraces at its potential frequency.	Relatively recent flood debris above banks and observations by Historic Site staff indicate stream is flowing and flooding lower terraces at its potential frequency.	Relatively recent flood debris above banks and observations by Historic Site staff indicate stream is flowing and flooding lower terraces at its potential frequency.
Beaver dams	n/a	n/a	n/a	n/a	n/a
Sinuosity, width/ depth ratio, and gradient	All appear to be in balance with landscape setting.	All appear to be in balance with landscape setting.	All appear to be in balance with landscape setting.	All appear to be in balance with landscape setting.	All appear to be in balance with landscape setting.
Riparian habitat area	Plains cottonwoods occupy low terraces in most of this reach. Riparian zone is near or at potential extent.	Sinuosity is reestablishing in a slightly incised channel, resulting in a widening riparian-habitat zone at this lower elevation.	Riparian zone is near or at potential extent. Plains cottonwoods occupy low terraces in most of this reach.	Riparian zone is near or at potential extent.	Riparian zone is near or at potential extent.
Upland watershed	No evidence of excessive sediment inputs or adverse changes to channel form.	No evidence of excessive sediment inputs or adverse changes to channel form.	Not reported for this stretch.	Not reported for this stretch.	Not reported for this stretch.
Vegetation					
Age class distribution of riparian habitat vegetation	Presently 3 age classes of plains cottonwood dating back to 1865 are present, but no recruitment since 1950s.	Plains cottonwood, recruitment age class is absent and 1950's era trees are found only in the downstream one-third of this reach.	Same as Reach #1.	Other than the few mature trees at the upstream end of the reach, cottonwoods are absent, and there is no recruitment age class.	One grove of plains cottonwoods in the upper part of this reach, but otherwise absent, with no recruitment age class.
Diverse vegetation composition	Plains cottonwood is essentially the only woody species present. A diverse, vigorous, soil-binding herbaceous plant community is likely to maintain channel stability in frequent to moderately frequent floods.	Plains cottonwood is the only woody species, and it is sparse compared to riparian zones immediately upstream and downstream. Same herbaceaous community as found along Reach #1.	A diverse assemblage of grasses and shrubs were present; however, larger woody vegetation was absent.	Plains cottonwoods mostly absent but herbaceous wetland-riparian vegetation is somewhat more diverse than in upstream reaches.	Plains cottonwoods mostly absent. Herbaceous wetland-riparian vegetation is somewhat more diverse than in upstream reaches.
Soil moisture characteristics	Soil appeared moist based upon the species present.	Soil appeared moist based upon the species present.	Species present were indicative of moist conditions and a rising water table possibly due to Tamarisk removal.	Channel is somewhat wetter.	Channel is wettest in this reach.
Plants have root masses capable of withstanding high streamflow events	All species present are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment.	Same as Reach #1.	Same as Reaches #1 and #2.	Herbaceous plant community in channel and on banks/floodplain is likely to maintain channel stability in frequent to moderately frequent floods. All species are rhizomatous.	Herbaceous plant community in channel and on banks/floodplain is likely to maintain channel stability in frequent to moderately frequent floods. All species are rhizomatous.

Table 4.8.4-1. Results for the riparian habitat condition assessment at* Sand Creek Massacre NHS (Martin et al. 2012) *continued.

Indicator/ Measure	Reach 1	Reach 2	Reach 3	Reach 4	Reach 5
Vigorous plants	Not reported for this stretch.	Cottonwoods appeared healthy and did not show stress commonly associated with water table drawdowns.	Cottonwoods at the upstream and downstream ends of this reach had more dead branches than in other areas, indicating possible water stress. Herbaceous communities maintain strong vigor, and upland species are not invading riparian zones.	Few cottonwoods, but herbaceous riparian-wetland community is vigorous in the channel and on the floodplain, with no invasion by upland species.	Cottonwoods have substantial decadent branches indicating water stress, possibly due to sustained high water table but herbaceaous communities exhibit high vigor.
Vegetation cover	Greater than 90% native cover on >90% of banks in this reach	Greater than 90% native cover on >90% of banks in this reach	Greater than 90% native cover on >90% of banks in this reach	Greater than 90% native cover on >90% of banks in this reach	Greater than 90% native cover on >90% of banks in this reach
Plant communities are source of large woody material (for maintenance/ recovery)	n/a	n/a	n/a	n/a	n/a
Erosion/Deposition					
Floodplain and channel characteristics	Channel is "on-grade," with floodplain no more than 2-3 feet above top of channel bank.	Channel somewhat more incised than in other reaches.	No evidence of adverse changes to channel form	Channel is "on-grade," but is sometimes indistinct and more of a wide, variable elevation swale.	Not reported for this stretch.
Point bars	n/a	n/a	n/a	n/a	n/a
Lateral stream movement	Movement has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces.	Lateral movement is related normal stream sinuosity and has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces.	Normal stream sinuosity and has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces.	Normal stream sinuosity and movement has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces.	Normal stream sinuosity and movement has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces.
Vertical stability	No evidence of vertical instability	No evidence of channel instability. Excavated ponds in this reach provide additional energy dissipation.	No evidence of vertical instability.	No evidence of vertical instability.	No evidence of vertical instability.
Balance of water and sediment	Not reported for this stretch.	Not reported for this stretch.	No evidence of excessive sediment inputs	No evidence of excessive sediment inputs or adverse changes to channel form.	No evidence of excessive sediment inputs or adverse changes to channel form.

fairly rare and short lived. More importantly, regular channel forming flows, those most responsible for channel migration, are also relatively rare. Consequently, geomorphic evolution of Big Sandy Creek channel is extremely slow compared to a stream that experiences a bankfull event every year or two.

Flood Frequency

The Colorado Water Conservation Board conducted a Log-Pearson III statistical analysis of the existing peak flow record (Lamar gage) for Big Sandy Creek to estimate flood recurrence intervals and associated magnitudes. The relatively short gage record of 23 years available at the time of the analysis produced an estimate for the 100-year flood of 2,577 cfs (CWCB, 1998). Other methods exist for estimating flood discharges, however, even with the short record of 23 years, using drainage specific data is usually preferred over other indirect methods. Consequently, we may accept this value as a

reasonable estimate of the 100-year flood for this drainage. Interestingly, Big Sandy Creek has experienced two floods in the range of the 100-year recurrence interval since measurements began in 1968. It is noteworthy that one of these extreme floods has occurred within the last decade or so since a large part of the PFC analyses deals with channel and flooplain stability during high flows.

Channel formation throughout the study area was weak, however there were areas where a distinct channel existed such as along reaches one and two. Where a primary channel was present, it was generally less than 0.5 meters deep and often only about 0.25 meters deep. Additionally, topwidth distances were usually less than three or four meters. Considering these small channel capacities, the overbank areas were likely to be inundated during any substantial flow event. In more "average" watersheds, an out of bank event would likely occur about every year or two but in the case of Big Sandy Creek, the frequency of such events is much less, more on the order of every five to ten years. Based upon the fluvial system within the hydrologic context of the Big Sandy Creek drainage, Martin et al. (2012) concluded that overbank flows occurred on a relatively frequent basis.

Field observations at the time of the site visit and measurements taken from LIDAR indicated that sinuosity (about 1.05), width to depth ratios (in the range of 20 - 30), and overall channel gradient (about 0.2 percent) suggested a balance between the channel form and the landscape setting. Although with weak channel formation, precise and consistent estimates of these geomorphic parameters were difficult to determine throughout all reaches, however, the measurements made were within, or very near the "stable" range.

Riparian Vegetation Condition

Riparian habitat vegetation serves a variety of functions in a river system including sediment capture, sources for woody debris, which in turn assists with energy dissipation, and creates habitat structure and food sources for several species. An integral part of the riparian habitat analysis was evaluation of the riparian vegetation present along the channel and floodplain. On the active floodplain and lowest terrace the only woody species (with two individual exceptions) was plains cottonwood, (*Populus deltoides*). Practically all of the individual cottonwood trees were within one of two age classes: 1948 to 1959 or 1908 to 1925 age class. Additionally, there was a scattering of individual trees from the 1865 to 1885 age class, mostly on the margins of the modern floodplain, but within about 100 meters of the channel and usually less than one meter higher in elevation.

Plains Cottonwoods (*Populus deltoides*)

The age class and structure of the mature cottonwoods present along Big Sandy Creek was one of the proxy indicators useful in assessing the recent history of the creek. In 2005, Lukas and Woodhouse (2006) from the institute of Arctic and Alpine Research in Boulder, Colorado conducted a detailed sampling of the cottonwoods within the Historic Site. The researchers identified three age classes along the drainage, with the oldest class having an estimated germination date range of 1865 – 1885 (note: one year after the 1864 massacre occurred). The two other age cases identified were 1908 – 1925 and 1949-1960. There has been little to no cottonwood establishment since 1960.

Also of interest to this assessment was the distribution of these age classes. Almost all of the cottonwoods present in the drainage were within 200 meters of the active channel and the vast majority were within 100 meters. The most recent age class, 1949 – 1960, was predominantly associated with the active channel. The two older classes were mostly located farther from the channel but still along the same general alignment. This arrangement strongly suggested that the active channel of Big Sandy Creek may have undergone some degree of migration since 1865, but the present alignment has been basically the same for the last 150 years or so.

Lastly, Martin et al. (2012) concluded that the initiation dates of the three age classes coincided well with probable flood events based on review of historical meteorological and hydrologic data. This also follows the

accepted model of cottonwood recruitment being associated with substantial floods.

Throughout the site, the dominant herbaceous varieties include: Chairmaker's bulrush (*Schoenoplectus americanus*), switchgrass (*Panicum virgatum*), western wheatgrass (*Pascopyrum smithii)* and inland saltgrass (*Distichlis spicata*), which cover channel bottoms, banks and low terraces. The species distribution appears to be related to water table depth. Potential for coyote willow (*Salix exigua*) was unknown since none were present during the time of the assessment.

All of the riparian vegetation present in the study area (with a few noted exceptions), appeared to exhibit high vigor and was indicative of sub-irrigated riparian soil. Cover was near 100 percent for the herbaceous assemblages providing good soil stabilization qualities. Additionally, Martin et al. (2012) concluded that the riparian corridor had reached or was approaching its potential width through all of the reaches and that the floral elements of the assessment were contributing to stream stability and a proper functioning condition rating throughout the site.

Erosion/Deposition Condition

Nowhere within the study area were any large deposits of sediment observed to suggest extensive upstream erosion. Also, no areas of significant erosion within or adjacent to the channel were observed. At one location in Reach 1, an apparent channel scour hole roughly 10 meters long and a recently deposited sand bar immediately downstream were observed, but this was not characteristic. Consequently, the researchers concluded that the channel and floodplain were able to pass the water and sediment being delivered by the watershed without excessive erosion or deposition and the watershed was not contributing to riparian habitat degradation.

In summary, the condition of the Historic Site's riparian habitat is a combination of vegetation, hydrology, and erosion and deposition factors and processes. These factors and processes are interconnected, and when evaluated as a whole, provide a comprehensive assessment of the Historic Site's riparian habitat. Table 4.8.4-2 summarizes the riparian habitat indicator categories and how they contributed overall to the assessment.

Historical Context

When the Cheyenne and Arapaho camps were attacked by Colonel Chivington and volunteers from Colorado's 1st and 3rd Regiments on November 29, 1864, the camps were located along Big Sandy Creek. Camp locations along creeks were typical since resources necessary for survival were found, such as water, shelter, and food sources for both people and pony herds.

The Big Sandy Creek and its physical features, such as the riverbanks where the Cheyennes and Arapahos dug holes to escape the attack, the river's geomorphology, and certain period trees are some of Sand Creek Massacre National Historic Site's fundamental resources (NPS 2006b) and these features are also part of its present day riparian habitat and floodplain.

Level of Confidence/Key Uncertainties

NPS' Water Resources Division and SOPN biologist/botanist conducted the riparian assessment through a technical assistance request to evaluate the functional condition of the Historic Site's riparian habitat area. Based on the expertise of the scientists, we're confident that the findings accurately reflected the condition of the Historic Site's riparian habitat at the time of the assessment.

Threats

According to Prichard et al. (1998), a state of resiliency within a riparian area needs to be maintained to respond to a high-flow event.

Different land use practices surrounding the Historic Site, such as grazing, may have impacted Plains cottonwood recruitment and establishment. The potential for coyote willow (*Salix exigua*) recruitment is unknown and none are present at this time (Martin et al. 2012).

Future alluvial groundwater withdrawals in the valley upstream have the potential to lower the water table, which could have adverse

Table 4.8.4-2. Summary of the riparian habitat indicators/measures categories and their contributions to the overall riparian habitat resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Hydrology (5 indicators)	The hydrology of a riparian area affects how well water flow energy can be dissipated, including erosion and sediment depositional processes. These hydrologic characteristics are also affected by upland watershed activities in addition to on-site activities/changes.	Relatively recent flood debris above banks and observations by Historic Site staff indicate stream is flowing and flooding lower terraces at its potential frequency, and no evidence of excessive sediment inputs or adverse changes to channel form from the upland watershed was observed.
Riparian Vegetation (7 indicators)	Riparian vegetation is specialized and controlled by how much water a plant's root system can withstand. Some are obligate wetland species, indicating the need for standing water in order to survive. Several different classes of wetland species also exist, and collectively provide the necessary cover, debris, and root systems to maintain resiliency during high flow events.	Plains cottonwood recruitment age class was absent and 1950's era trees were found only in the downstream one-third of this reach, but a diverse assemblage of grasses and shrubs were present throughout. All stream stretches had greater than 90% native cover on >90% of their banks.
Erosion/Deposition (5 indicators)	Erosion and sediment deposition is a natural and necessary process for a river and its riparian habitat to maintain dynamic equilibrium. Properly functioning conditions manifest as channel and floodplain "intactness", lack of channel braiding, or streambank failure. Lateral movement also implies erosion and depositional balance.	Normal stream sinuosity and movement has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces, and no evidence of vertical instability or excessive sediment inputs or adverse changes to channel form was observed.

effects on existing cottonwoods or future recruitment, and could alter herbaceous species composition (Martin et al. 2012).

Lastly, non-native plants *Kochia scoparia* observed on channel banks and bottom in some areas and *Salsola tragus* (prickly Russian thistle) were observed on some upper bank and terrace locations, but neither were considered to be dominant species.

4.8.5. Sources of Expertise

The National Park Service's Water Resources Division scientists, Mike Martin, Kevin Noon, and Joel Wagner provide leadership for the preservation, protection, and management of the water and aquatic resources in the NPS.

Tomye Folts-Zettner, Southern Plains Inventory and Monitoring Network Botanist, also assisted with the riparian assessment, providing plant identification expertise.

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4.9. Grasslands

Indicators/Measures

- Hydrology Soil/Site Stability and Hydrologic Function (10 Indicators)
- Biotic Integrity (5 indicators)

Condition – Trend - Confidence



Good – Improving - High

Grasslands as a whole are essentially the dominant vegetation type of Sand Creek Massacre NHS. Even vegetation types that may be formally classified as a shrubland (e.g., Sand Sage (*Artemisia filifolia*) or woodland (e.g., Cottonwood (*Populus spp.*)) communities, have a pronounced grassland component.

4.9.1. Background and Importance

The central grassland region of North America is one of the largest contiguous grassland environments on earth (Lauenroth et al. 2008), and depending on which classification is used, there are at least three distinct grassland types: tallgrass prairie, mixed grass prairie, and shortgrass steppe (prairie). Sand Creek Massacre NHS is located with the region generally classified as shortgrass steppe (Figure 4.9.1-1). The shortgrass steppe is located in the warmest and driest area and is the least productive of all grassland types, uniquely adapted to survive drought conditions (Lauenroth et al. 2008). The species that characterize the archetypal shortgrass steppe are blue grama (*Bouteloua gracilis*) and buffalo grass (*Buchloe dactyloides*).

Grasslands at Sand Creek Massacre NHS

While Sand Creek Massacre NHS is situated within the broad category of shortgrass steppe there is also considerable variation in grasslands throughout the Historic Site (Neid et al. 2007, Roath et al. 2008). The Colorado Natural Heritage Program conducted vegetation classification and mapping at Sand Creek Massacre NHS as part of the USGS-NPS Vegetation Characterization Program; a cooperative effort by the U.S. Geological Survey (USGS) and the National Park Service (NPS) to classify, describe, and map vegetation communities in more than 280 national park units across the United States. This program uses a hierarchical classification scheme, the National Vegetation Classification Standard (http://biology.usgs.gov/npsveg/nvcs.html), as a basis for classifying vegetation.



PHOTO CREDIT: HEIDI SOSINSKI

Figure 4.9.1-1 . Grassland at Sand Creek Massacre NHS.

The Colorado Natural Heritage Program identified six different National Vegetation Classification (NVC) associations, within 10 mapping units. The six plant associates consisted of one cottonwood-dominated woodland, two sand sage-dominated shrublands, and three that were grassland dominated (Neid et al. 2007) (Figure 4.9.1-2) (Table 4.9.1-1).

As with most ecological communities, shortgrass prairie system driver patterns have changed. Early Land use consisted primarily of Native Americans hunting the open plains for bison. In the years following the 1864 massacre land use of the grasslands shifted to open cattle grazing, which later gave way to stock farming and other agriculture.

As settlement continued, changes in fire patterns and fire frequency followed. The absence of fire is generally thought to have contributed to an increase in sand sage in the southwest grassland areas. In addition to herbivory and fire, climate change is and will continue to increasingly impact the shortgrass prairie region, creating changes in temperature and precipitation patterns and amounts (Morgan et al. 2008), which in turn will affect the plants and animals native to the shortgrass ecosystem.

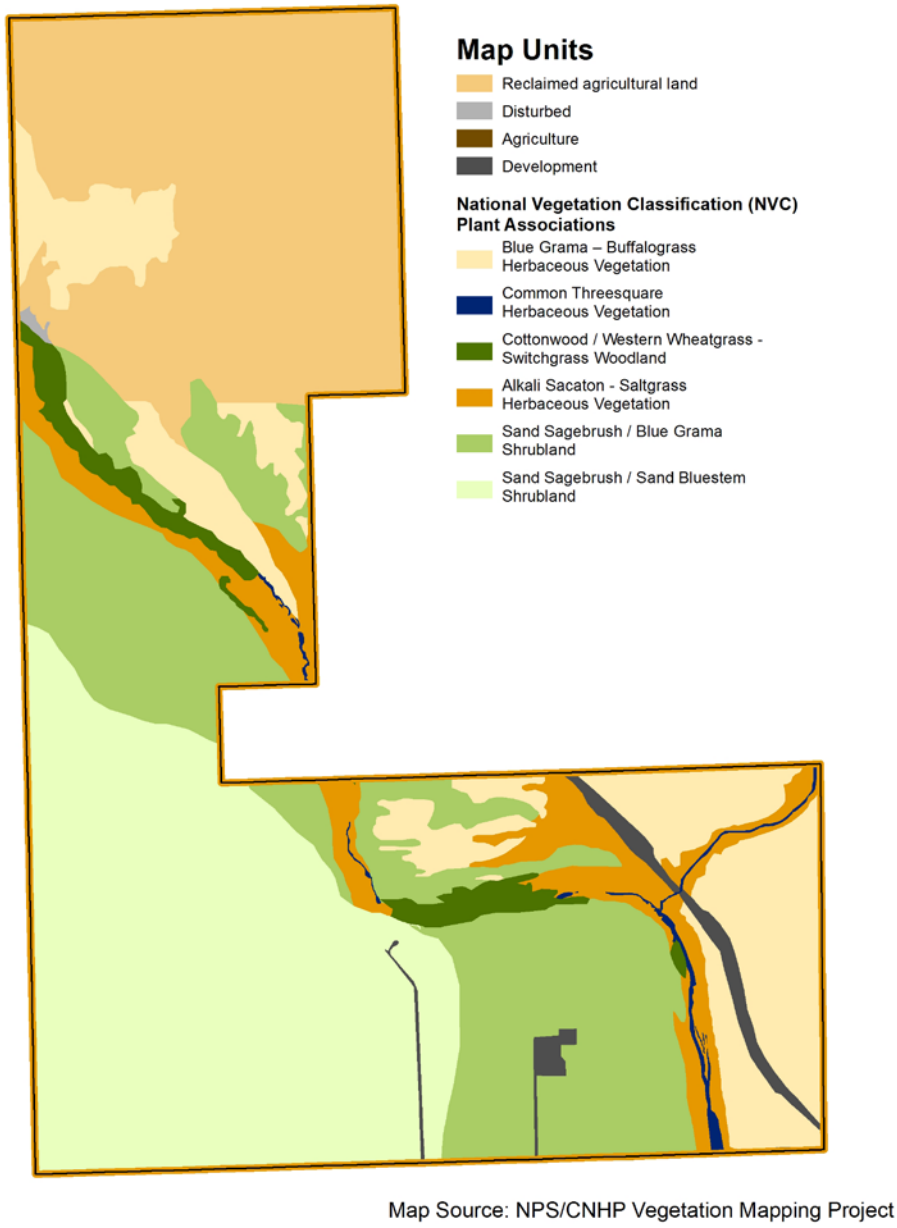


Figure 4.9.1-2. The ten map classes identified by Nied et al. (2007) including the six plant alliances used by the National Vegetation Classification (NVC) system.

Table 4.9.1-1. The six different National Vegetation Classification (NVC) plant associations identified by the Colorado Natural Heritage Program and their corresponding area occupied.

NVC Plant Association	Primary Class	Area (hectares / acres)
Plains Cottonwood / Western Wheatgrass – Switchgrass	Woodland[1]	22.4 ha / 55.4 ac
Sand Sagebrush / Sand Bluestem	Shrubland[1]	273.9 ha / 676.9 ac
Sand Sagebrush / Blue Grama	Shrubland[1]	217.6 ha / 537.8 ac
Blue Grama– Buffalograss	Grassland	140.6 ha / 347.3 ac
Common Threesquare	Grassland	4.8 ha / 11.8 ac
Alkali Sacaton – Inland Saltgrass	Grassland	63.2 ha / 156.2 ac

[1]Includes a prominant grass component

Historic Context

Grasslands at Sand Creek Massacre NHS are clearly part if its cultural heritage. Consultations with the Cheyenne and Arapaho tribes have identified protection of the landscape as one of highest natural resource priorities at the Historic Site. The grasslands were home to native cultures and the native flora and fauna, most notably, the vast herds of buffalo, were essential the way of life for the plains tribes (Figure 4.9.1-3).

Conditions During Assessment

It is important to recognize that a major drought occurred during the time period of this assessment. During the summer of 2010, Sand Creek Massacre NHS was experiencing conditions that were in the midrange of variability. However, in 2011 and 2012 the site was experiencing extreme drought conditions (Figure 4.9.1-4). We have tried to take these conditions into account in our interpretations, but the reader should be aware that such conditions may have an important impact on our assessment.

4.9.2. Data and Methods

There were seven primary information/data sources used for this assessment. Of these five were used for background information and to aid us in formulating reference conditions. We used the vegetation mapping effort for Sand Creek Massacre NHS conducted by by Neid et al. (2008) of the Colorado Natural Heritage Program. Ecological Site Descriptions (NRCS 2007) provided background information for



Figure 4.9.1-3. One of the values of grasslands, is the importance that they played in the historic context. The ability for visitors to imagine the historic setting can dramatically add to their sense of place in that historic context.

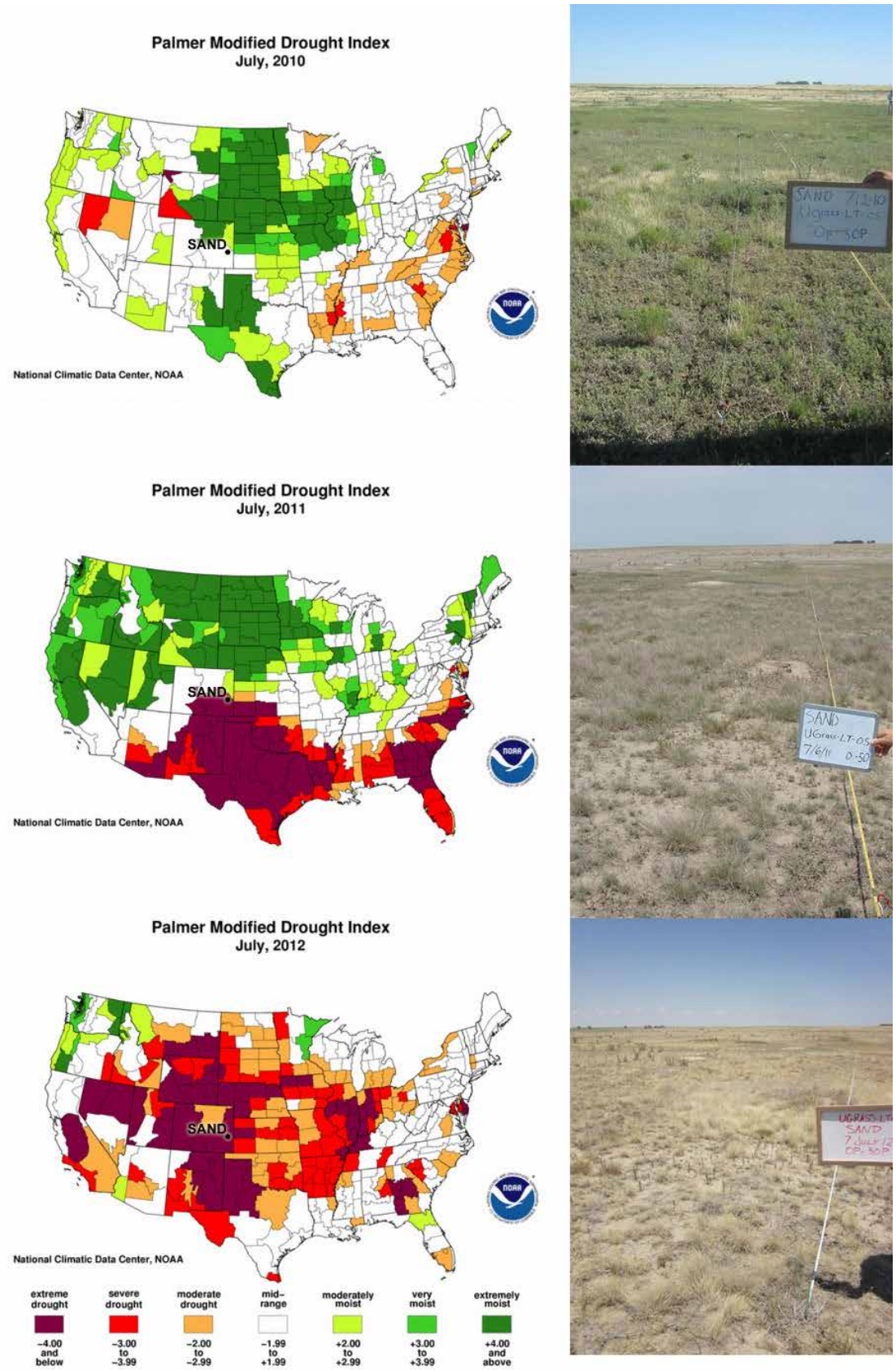


Figure 4.9.1-4. The Palmer Drought Index for each of the three years for which data from Sand Creek Massacre NHS were available. Also shown to the right of each map are photos taken from a monitoring transect (UGRASS-LT05) for the corresponding time period.

the ecological site types found at Sand Creek. Both a vegetation inventory (Roath et al.2008) and a preliminary (unfinished) report of the range of natural variation (Roath et al., unpublished) were conducted, and based largely on the Ecological Site Descriptions. An additional project aimed at reviewing synthesizing a number previous reports for Sand Creek (Seastedt 2008) also provided background information. Two additional sources of information and data were used for the assessment itself. The first was a rapid site assessment (discussed in greater detail below) conducted by NPS Soil Scientist Peter Biggam, grassland experts Alan Knapp and Tim Seastedt, and SOPN biologist/botanist Tomye Folts-Zettner. The second source was data collected by the Southern Plains Inventory and Monitoring Program and the Southern Plains Fire Group.

We considered three categories of measures/ indicators for the assessment of grassland condition at the Historic Site based on the approach presented by Pellant et al. (2005): soil/site stability, hydrologic functioning, and biological integrity. These categories are defined by Pellant et al. (2005) as follows:

Soil/Site Stability - The capacity of an area to limit redistribution and loss of soil resources (including nutrients and organic matter) by wind and water.

Hydrologic Function - The capacity of an area to capture, store, and safely release water from rainfall, run-on, and snowmelt (where relevant), to resist a reduction in this capacity, and to recover this capacity when a reduction does occur.

Biotic Integrity -The capacity of the biotic community to support ecological processes within the normal range of variability expected for the site, to resist a loss in the capacity to support these processes, and to recover this capacity when losses do occur. The biotic community includes plants, animals, and microorganisms occurring both above and below ground.

In combination, the measures/indicators from each of these categories provide the basis for this assessment. We have summarized the indicators for each of these groups below.

Indicators/Measures

Soil/Site Stability and Hydrologic Function

The soil/ site stability/hydrologic function indicators were assessed primarily through a site visit and rapid assessment in May 2012 conducted by Pete Biggam, (Biggam 2013) who is a soil scientist with NPS' Geoscience and Restoration Branch. Biggam's full report is presented in Appendix D).

The rapid soil assessments consisted of evaluating eight selected sites on the lands that the NPS currently manages (Figure 4.9.2-1). Areas within the Historic Site that are still under private ownership were not assessed. Locations of these sites can be found at http://websoilsurvey.sc.egov.usda.gov/app/HomePage.html.

The methodology used for these assessments used an approach based on those described in the qualitative assessment protocol "Interpreting Indicators of Rangeland Health (Version 4.0) (http://usda-ars.nmsu.edu/monit_assess/index.html), in which Soil/Site Stability qualitative indicators (Table 4.9.2-1) were used to assess the ability of an area to limit redistribution and loss of soil resources by wind and water.

Qualitative indicators can provide land managers and technical assistance specialists with a good communication tool, and when used in association with quantitative monitoring and inventory information, they can be used to provide early warnings of resource problems on upland rangelands.

These indicators were used in conjunction with soil survey information and ecological site descriptions for the eight selected evaluation areas, each of which were approximately 1/3 acre in size. It is important to note that only the Soil/Site Stability qualitative indicators were observed and documented on site, and these were what were used to perform the rapid soil assessments. The rapid soil assessment was

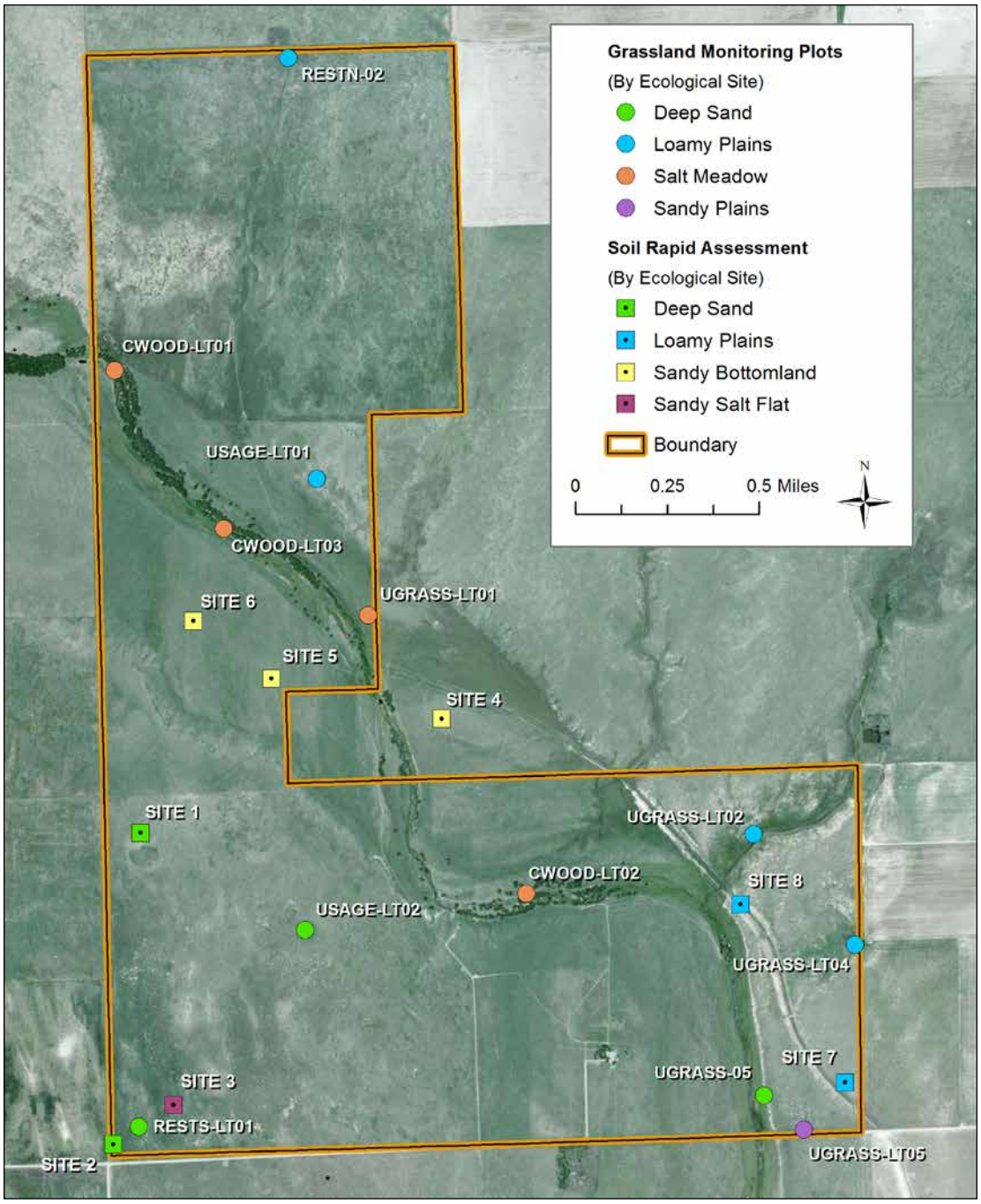


Figure 4.9.2-1. Location of Soil Rapid Assessment points and grassland monitoring plots at Sand Creek Massacre NHS.

used to determine the departure from the expected soil/site stability attributes.

Indicators/Measures

Biotic Integrity

The assessment for the biotic integrity of grasslands was made via a combination of a field assessment by grassland experts Alan Knapp (Colorado State University) and Tim Seastedt (University of Colorado at Boulder) and data collected as part of the Southern Plains Network's ongoing grassland monitoring. In collaboration with additional SOPN and Historic Site staff, the first task was to determine appropriate indicators of grassland biotic integrity. Using the qualitative indicators of rangeland health presented in (Pellant et al. 2005) as a starting point, the grassland experts, in collaboration with SOPN and Historic Site staff developed a suite of five indicators of grassland biotic integrity that was deemed appropriate for this assessment. These indicators are summarized in Table 4.9.2-2 and described in greater detail below.

Table 4.9.2-1. Indicators/measures used to assess the soil/site stability and hydrologic function of grasslands at Sand Creek Massacre NHS.

Indicator/Measure	Definition
Rills	A small, intermittent water course with steep sides, usually only several centimeters deep (SSSA 1997). Rills generally are linear erosion features.
Water Flow Patterns	Flow patterns are the path that water takes as it moves across the soil surface during overland flow.
Pedestals and/or terracettes	"Plants or rocks that appear elevated as a result of soil loss by wind or water erosion (does not include plant or rock elevation as a result of non-erosional processes such as frost heaving), and "Benches" of soil deposition behind obstacles caused by water erosion."
Bare ground	All land surface not covered by vegetation, rock, or litter (SRM 1999). As used in this document, visible biological crusts and standing dead vegetation are included in cover estimates or measurements and therefore are not bare ground (e.g., mineral soil).
Gullies	A furrow, channel, or miniature valley, usually with steep sides through which water commonly flows during and immediately after rains or snowmelt (SRM 1999). Small channels eroded by concentrated water flow.
Wind-scoured, blowout and/or depositional areas	Areas, generally in interspaces, where the finer soil particles have blown away sometimes leaving residual gravel, rock, or exposed roots on the soil surface
Litter Movement	The uppermost layer of organic debris on the soil surface, essentially the freshly fallen or slightly decomposed vegetal material (SRM 1999). In this document, it includes persistent and non-persistent organic matter that is in contact with the soil surface.
Soil surface resistance to erosion	The top layer underneath vegetation canopy and characteristics of presence/absence/configuration of debris
Soil surface loss or degradation	Intactness of uppermost soil layer
Compaction layer	A near surface layer of dense soil caused by the repeated impact on or disturbance of the soil surface. When soil is compacted, soil grains are rearranged to decrease the void space and bring them into closer contact with one another, thereby increasing the bulk density (SSSA 1997).

Table 4.9.2-2. Indicators of grassland biotic integrity developed for this assessment.

Indicator	Description
Species Composition, Landscape-scale Diversity	The extent to which landscape-scale diversity reflects spatial pattern of soils and disturbance.
Species Composition, Local scale	The extent to which species composition within a site (e.g., ecological site) deviates substantially from the expected native species compliment either from exotics or native species.
Response of Annual Species to Disturbance	The extent to which annual species persist in sites not recently disturbed, compared to undisturbed and recently disturbed sites.
Relative proportion of functional groups (e.g., graminoid, forbs, shrubs, etc.)	The relative proportions of functional groups relative to what would be expected based on site characteristics (e.g., lack of forbs, excessive shrub density, etc.)
Relative proportion of C3 and C4 species.	The relative proportions of f C3 and C4 plants relative to what would be expected based on site characteristics

Based on these indicators, a rapid field assessment was conducted based on visits to multiple sites at Sand Creek Massacre NHS. Each site was qualitatively evaluated by the experts based on the indicators developed. We then used data collected during the past three years of monitoring to augment the opinions by our experts and to provide a more quantitative baseline for future assessment. These data were collected by the Southern Plains Inventory and Monitoring Network (SOPN) and the Southern Plains Fire Group, following Folts-Zettner et al (2013a). Grassland monitoring data were collected in

2010-2012 along 12 transects, each with five subplots, as part of this monitoring effort (Folts-Zettner et al 2012, 2013b) (Figure 4.9.2-1). At each subplot, the percent cover was estimated for each species within a 1x2m^2 quadrat.

Species Composition, Landscape-scale Diversity

The local species composition generally reflects local conditions of soils, moisture, disturbance, etc. As such, we would expect the diversity across a broader region to generally reflect the variation in these site characteristics. However, it is not reasonable to expect a one to one correspondence between local communities and their corresponding sites because a multitude of factors can influence the local expression of vegetation communities at a given site. Rather, we are trying to determine that some reasonable level of landscape diversity exists and that it generally corresponds to changes in ecological conditions.

Local Scale Species Composition

The intent behind this indicator is to see if the species composition is generally consistent with what might be expected for the site, given the local conditions (soils, disturbance, moisture, etc). We considered this using two measures. First, was the degree to which the local species consisted of native vs exotic species. Details about which exotic species are present and their effect on the site are presented in greater detail in Chapter 4.11. Here we just provide an initial indicator of the extent of invasion by exotic species by looking at the proportion of native and exotic species. Second, we looked at the species composition of the native species relative to what might be expected for that site. This was based on a combination of NRCS Ecological Site Descriptions and expert opinion. As we have done for other indicators, this assessment is based primarily on percentage cover, rather than the number of individual species because most species are quite rare and cover provides a more realistic assessment of the impact of exotic invasion. However, we do present the proportion of individual species as well merely as an ancillary reference.

Response of Annual Species to Disturbance

It is generally expected that the number of annual species at a given site would be higher immediately following a disturbance, and would shift toward an increasing number of perennials as time passes since a disturbance. The persistence of annuals after a disturbance could indicate some basis for concern. For example roadside areas that are frequently and unnaturally disturbed might be expected to have a greater persistence of annual species compared to interior sites.

Relative Proportion of Functional Groups

The composition of functional groups can have a dramatic effect of grassland ecosystems and their associated processes (Tilman et al. 1997, Pellant et al. 2005). Tilman et al. (1997) found that functional composition and functional diversity were principal factors explaining plant productivity, plant percent nitrogen, plant total nitrogen, and light penetration. They further concluded that habitat modifications and management practices that change functional diversity and functional composition would likely have a dramatic effect on ecosystem processes.

Relative Proportion of C3 and C4 Species -

Shortgrass Prairies are typically dominated by perennial C4 (warm season) grasses (Lauenroth 2008). The morphological and physiological characteristics of these plants make them highly adaptable to withstand stressors such as drought or grazing by large herbivores such as cattle((Lauenroth 2008). The proportion of C3 and C4 grasses can also dramatically influence how these grassland communities respond to climate change and levels of CO_2, although the nature of such response has been much debated (Wand et al. 1999).

4.9.3. Reference Conditions

Soil/Site Stability and Hydrologic Function

Pellant et al. (2005) described general reference conditions they considered to be an optimal functional state (their none to slight category) under natural disturbance regimes (Table 4.9.3-1). They then described general descriptions for departures from that optimal state into four other categories of

Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function and biotic integrity indicators.

Indicator	Significant Concern		Moderate Concern	Good	
	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil/site Stability and Hydrologic Function					
Rills	Rill formation is severe and well defined throughout most of the site.	Rill formation is moderately active and well defined throughout most of the site.	Active rill formation is slight at infrequent intervals; mostly in exposed areas	No recent formation of rills; old rills have blunted or muted features.	Current or past formation of rills as expected for the site.
Water Flow Patterns	Water flow patterns extensive and numerous; unstable with active erosion; usually connected	Water flow patterns more numerous and extensive than expected; deposition and cut areas common; occasionally connected.	Number and length of water flow patterns nearly match what is expected for the site; erosion is minor with some instability and deposition.	Number and length of water flow patterns match what is expected for the site; some evidence of minor erosion. Flow patterns are stable and short.	Matches what is expected for the site; minimal evidence of current or past soil deposition and erosion.
Pedestals and/or terracettes	Abundant active pedestalling and numerous terracettes. Many rocks and plants are pedestaled; exposed plant roots are common.	Moderate active pedestalling; terracettes common. Some rocks and plants are pedestaled with occasional exposed plant roots.	Slight active pedestalling; Most pedestals are in flow paths and interspaces and/or on exposed slopes. Occasional terracettes present.	Active pedestalling or terracette formation is rare; some evidence of past pedestal formation, especially in flow patterns on exposed slopes.	Current or past evidence of pedestaled plants or rocks as expected for the site. Terracettes uncommon or absent.
Bare ground	Much higher than expected for the site. Bare areas are large and generally connected.	Moderate to much higher than expected for the site. Bare areas are large and occasionally connected.	Moderately higher than expected for the site. Bare areas are of moderate size and sporadically connected.	Slightly to moderately higher than expected for the site. Bare areas are small and rarely connected.	Amount and size of bare areas match that expected for the site.
Gullies	Common with indications of active erosion and downcutting; vegetation is infrequent on slopes and/or bed. Nickpoints and headcuts are numerous and active.	Moderate in number to common with indications of active erosion; vegetation is intermittent on slopes and/or bed. Headcuts are active; downcutting is not apparent.	Moderate in number with indications of active erosion; vegetation is intermittent on slopes and/or bed. Occasional headcuts may be present.	Uncommon, vegetation is stabilizing the bed and slopes; no signs of active headcuts, nickpoints, or bed erosion.	Match what is expected for the site; drainages are represented as natural stable channels; vegetation common and no signs of erosion.
Wind-scoured, blowout, and/or depositional areas	Extensive	Common	Occasionally present	Infrequent and few.	Match what is expected for the site.
Litter movement	Extreme concentrated around obstructions. Most size classes of litter have been displaced.	Moderate to extreme; loosely concentrated near obstructions. Moderate to small size classes of litter have been displaced.	Moderate movement of smaller size classes in scattered concentrations around obstructions and in depressions.	Slightly to moderately more than expected for the site with only small size classes of litter being displaced.	Matches that expected for the site with a fairly uniform distribution of litter.
Soil surface resistance to erosion	Extremely reduced throughout the site. Biological stabilization agents including organic matter and biological crusts virtually absent.	Significantly reduced in most plant canopy interspaces and moderately reduced beneath plant canopies. Stabilizing agents present only in isolated patches.	Significantly reduced in at least half of the plant canopy interspaces or moderately reduced throughout the site.	Some reduction in soil surface stability in plant interspaces or slight reduction throughout the site. Stabilizing agents reduced below expected	Matches that expected for the site. Surface soil is stabilized by organic matter decomposition products and/or a biological crust.

Table 4.9.3-1. Reference conditions for soil/site stability/hydrologic function and biotic integrity indicators (continued).

Indicator	Significant Concern		Moderate Concern	Good	
	Extreme to Total	Moderate to Extreme	Moderate	Slight to Moderate	None to Slight
Soil surface loss or degradation	Soil surface horizon absent. Soil structure near surface is similar to, or more degraded, than that in subsurface horizons. No distinguishable difference in subsurface organic matter content.	Soil loss or degradation severe throughout site. Minimal differences in soil organic content and structure of surface and subsurface layers.	Moderate soil loss or degradation in plant interspaces with some degradation beneath plant canopies. Soil structure is degraded and soil organic matter is significantly reduced.	Some to no soil loss has occurred and/or soil structure shows signs of degradation, especially in plant interspaces	Soil surface horizon intact. Soil structure and organic matter content match that expected for site.
Compaction layer (below soil surface)	Extensive; severely restricts water movement and root penetration.	Widespread; greatly restricts water movement and root penetration.	Moderately widespread, moderately restricts water movement and root penetration.	Rarely present or is thin and weakly restrictive to water movement and root penetration.	Matches that expected for the site; none to minimal, not restrictive to water movement and root penetration.

condition. These categories ranged from their optimal state to an extreme or total state of degradation.

We considered the condition of grasslands as "good" if the current condition fell either within Pellant et al.'s (2005) "none to slight", or "slight to moderate" categories. The "moderate" ranking was assigned if the departure from optimal fell within Pellant et al's (2005) "moderate" class. And finally, we considered the condition of grasslands as a "significant concern" if the departure from optimal fell within Pellant et al's (2005) "moderate to extreme" or "extreme to total" classes.

Biotic Integrity

Determining definitive quantitative reference conditions for grassland communities at Sand Creek Massacre NHS is somewhat problematic given the dynamic nature of these resources. Part of our consideration in choosing the indicators we have used for biotic integrity is that are moderately robust to the potentially substantial seasonal and annual variation that plant communities often exhibit. We began with a conceptual framework for assigning condition based on what might be expected for the site conditions at Sand Creek Massacre NHS (Table 4.9.3-2). We recognize, however, that seasonal and annual variation in such things as rainfall and disturbance can results in dramatic shifts in specific measurement that are still within an acceptable range of natural variation.

Our indicator of landscape-scale diversity focuses on whether or not the diversity of plant communities reflects to a reasonable extent the diversity in site characteristics. As such, we used the spatial pattern of soil types (NRCS 2012) and ecological sites (NRCS 2007) as a general reference for the extent and pattern of landscape diversity that might be expected.

For the remaining indicators, we used the Natural Resources Conservation Service's ecological site descriptions (NRCS 2007 which was reiterated in Roath et al., unpublished report), as a very general reference for plant community characteristics that might be expected given the soil types and ecological sites that occur at Sand Creek Massacre NHS. It is important to note however, the values in the site descriptions are typically only provided for what are considered the historic late seral plant communities (HCPCs), and variations in the dynamics of those communities are presented only through qualitative descriptions and/or generalized state and transition models. One to one correspondence between site description HCPCs and site specific conditions is rather limited. Seastedt (2008) also advised against

Table 4.9.3-2. Reference conditions used to assess the current condition for indicators of grassland biotic integrity.

Indicator	Significant Concern	Moderate Concern	Good
Landscape- scale diversity	Significant lack of spatial landscape heterogeneity that does not reflect the expected diversity for the soil types and sites	Moderate lack of spatial landscape heterogeneity that does not fully reflect the spatial pattern of soils and disturbance	Landscape-scale diversity reflects spatial pattern of soils and disturbance
Local scale species composition	Species composition deviates substantially from the native species compliment that would typically occur at such sites. Such a deviation could also be either from exotics or native species.	Species composition moderately deviates from the expected native species compliment either from exotics or native species in such a way that that does reflect typical types of natural disturbance (e.g., fire or prairie dogs).	Species composition reflects expected native species compliment consistent with the site characteristics (e.g., from ESDs). Species composition need not reflect expected late seral communities if their current state reflects typical types of natural disturbance (e.g., fire or prairie dogs).
Annual, biennial and perennial species relative to Disturbance	Substantially higher proportion of annual species than expected in sites not recently disturbed.	Proportion of perennial species is moderately lower that what might be expected given the site and time since disturbance.	Proportion of perennial species is approximately what would be expected given the site and time since disturbance.
Relative proportion of functional groups (e.g., graminoids, forbs, shrubs, etc.)	Proportions of functional groups differ substantially from what might be expected based on- site characteristics (e.g., lack of forbs, excessive shrub density, etc.)	Proportions of functional groups exhibit moderately departure from what might be expected given the site and disturbance history.	Proportions of functional groups (e.g., grasses, forbs, and shrubs) are consistent with what might be expected given the site characteristics.
Relative proportion of C3 and C4 species.	Sites dominated by C3 grasses at shortgrass sites traditionally dominated by C4 grasses.	Higher than expected proportion of C3 grasses given the ecological site and disturbance history.	Appropriate mix and natural variability of C4 (warm season) and C3 (cool season) grasses for the site (to maximize resilience)

using the HCPCs presented in NRCS 2207 or Roath et al. (unpublished report) as a sole guide for restoration of Sand Creek Massacre NHS grasslands. Consequently we do not strictly adhere to the HCPCs as a reference condition in the sense that departures from that reference necessarily represent a degraded quality; rather as a general guide to be used in conjunction with the state and transition models, descriptions of the alternative communities represented by the site dynamics, as well as other ecological considerations from the literature or grassland experts.

4.9.4. Condition and Trend

Soil/Site Stability / Hydrologic Function

The results from Biggam's rapid assessment indicated that the overall current condition of the soil/site stability/hydrologic function at Sand Creek Massacre NHS was good, with departures from expected generally being slight to moderate (Table 4.9.4-1). A more detailed assessment for each of the indicators is presented in the full report (Biggam 2013, Appendix D).

Biotic Integrity

Species Composition, Landscape-scale Diversity

The patterns of plant community distribution generally match that of the ecological sites and soils (Figure 4.9.4-1); although there is less detail in the breakdown of communities, particularly relative to soil types. This lack of fine scale diversity may merely reflect the classification process of plant communities rather than an absence of any expected diversity. Further, during the rapid assessment, our grassland experts did not express any concern over a lack of landscape diversity and felt that this aspect was in very good condition. Thus, we consider landscape scale diversity as being in good condition with no evidence for any degrading trend.

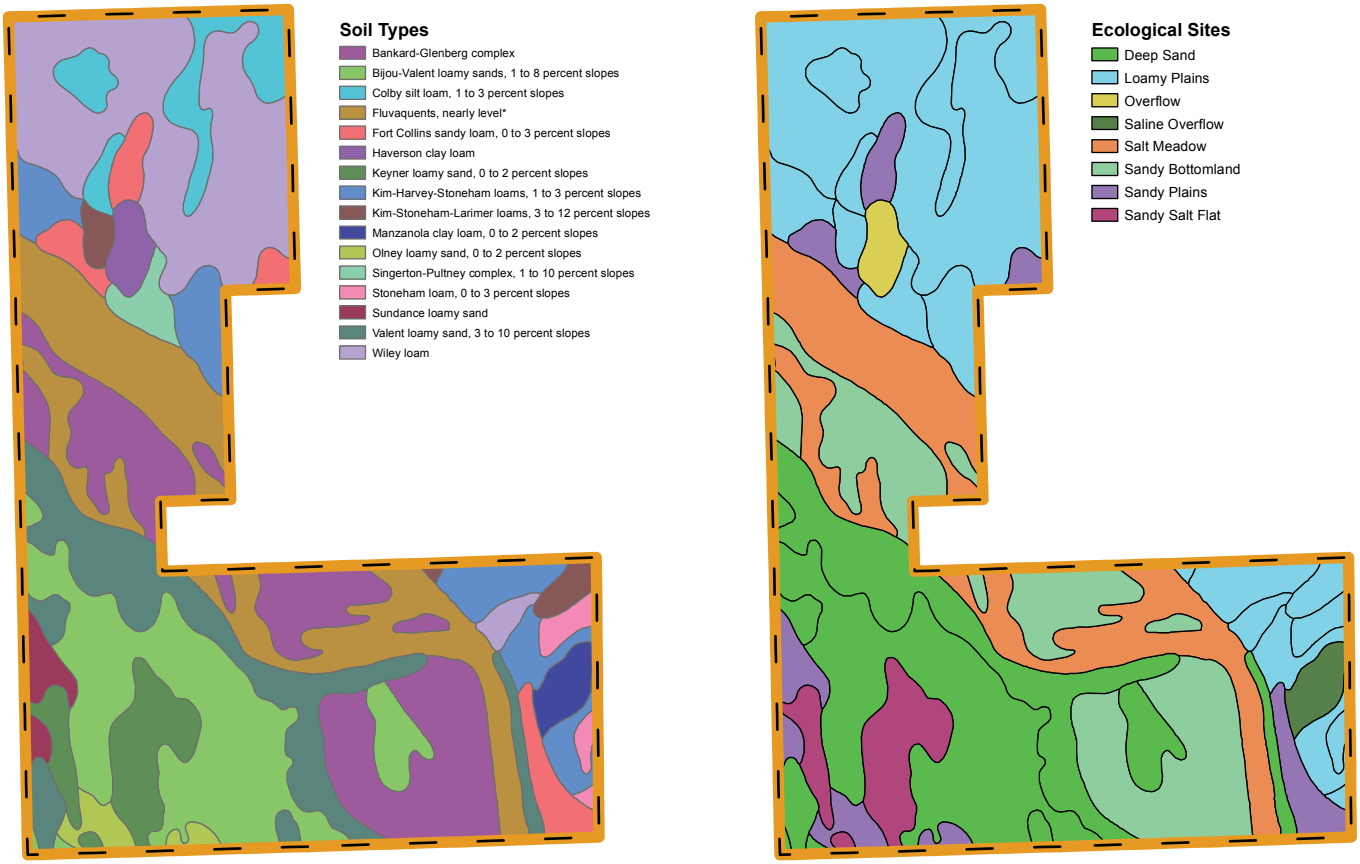


Figure 4.9.4-1. The distribution of soil types based on NRCS (2012) (top left), ecological sites based on NRCS (2007) (top right) and plant communities based on Nied et al. (2007) (bottom).

Local Scale Species Composition

As previously indicated, we do not have an expectation for species composition to exactly match the species list for historic late seral plant communities (NRCS 2007), in part because of local variability of micro sites as well as temporal variability such as seasonal or annual variation in rainfall etc. In addition, not all sites at Sand Creek Massacre NHS are in a late seral state given their history of disturbance. However, the ecological site descriptions do provide a crude indication of what species might be expected. The lists of species that we observed as well as the lists of species reported for historic late seral plant communities from those site descriptions

Table 4.9.4-1. Current condition relative to reference condition for the soil/site stability and hydrologic function indicators reported by Biggam (Appendix D).

Site Number	Site Name	Ecological Site Documented at the Site	Soil Assessment and Departure from Expected Conditions
1	Big Head Site	Deep Sand (R069XY019CO)	None to Slight
2	Access Road Area	Deep Sand (R069XY019CO)	Slight to Moderate
3	Stabilized Blow out with slick spots	Sandy Salt Flat (R069XY032CO)	None to Slight
4	Ditch Borrow Area	Sandy Bottomland (R069XY031CO)	Slight to Moderate
5	Range Mowing Site 1	Sandy Bottomland (R069XY031CO)	None to Slight
6	Range Mowing Site 2	Sandy Bottomland (R069XY031CO)	None to Slight
7	Prairie Dog Town	Loamy Plains (R069XY006CO)	None to Slight
8	Eroded Drainage Bank	Loamy Plains (R069XY006CO)	Slight to Moderate*

* The assessment was a composite of the "Moderate to Severe" departure documented within the active gully, and the "None to Slight"departure in the upland areas within the total assessment area, resulting in a "Slight to Moderate" departure for the entire site.

are located at (http://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD&state=CO&mlra=). When considering the condition of Sand Creek Massacre NHS' grasslands, we tried to take into account not only the ecological site, but also the other factors discussed above that influence species composition.

Not surprisingly, species composition at several sites did not closely match the HCPCs; however there were no departures that raised high levels of concern. Departures from HCPC expectations tended to correspond with areas that had been substatially disturbed. For example, many of our samples on the loamy plains sites coincided with CRP lands that were previously in agriculture. Strictly from a standpoint of ecological health/function, the CRP lands are in good functional condition, but are less consistent with historical species composition than adjacent shortgrass prairie. This does not currently appear to be an active management concern, nor was it of concern to our subject matter experts.

Similarly, historic prairie dog colonies tended to be dominated by red three awn, which is an expected state noted for such disturbance in the State and Transition Models of the Ecological Site Descriptions. These and other areas of disturbance tended to have a high proportion of perennial native species and all indications are that they are on a trajectory that is generally consistent with disturbed areas for these ecological sites. These sites may, however, warrant closer monitoring to determine if/when active management may be desired to move the species composition closer to an historic condition. Abandoned mounds are also sources of invasive species that should be watched to ensure they do not invade; an option is to spot-seed the mounds.

Annual vs Native Species -- One of the major threats to grasslands and other plant communities is invasive species. Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), and changes in water availability (D'Antonio and Mahall 1991).

Based on three years (2010-2012) of grassland sampling 86 of 93 (92%) of the species we observed were native (Table 4.9.4-2). However, the number of species does not take into account how prevalent those species are on the landscape. Based on the percentage of cover, grasses on sample plots were almost exclusively native species and with a few exceptions (e.g., the sandy plains ecosite in 2012), forbs were also predominately native species (Figure 4.9.4-2).

Table 4.9.4-2. The number and percentage of native and exotic species of each life form found on Sand Creek Massacre NHS during the 2010-2012 grassland monitoring sampling.

Life Form	Native	Exotic	Total	Percent Native
Graminoid	17	1	18	94%
Forb	62	6	68	91%
Shrub	3	0	3	100%
Subshrub	3	0	3	100%
Tree	1	0	1	100%

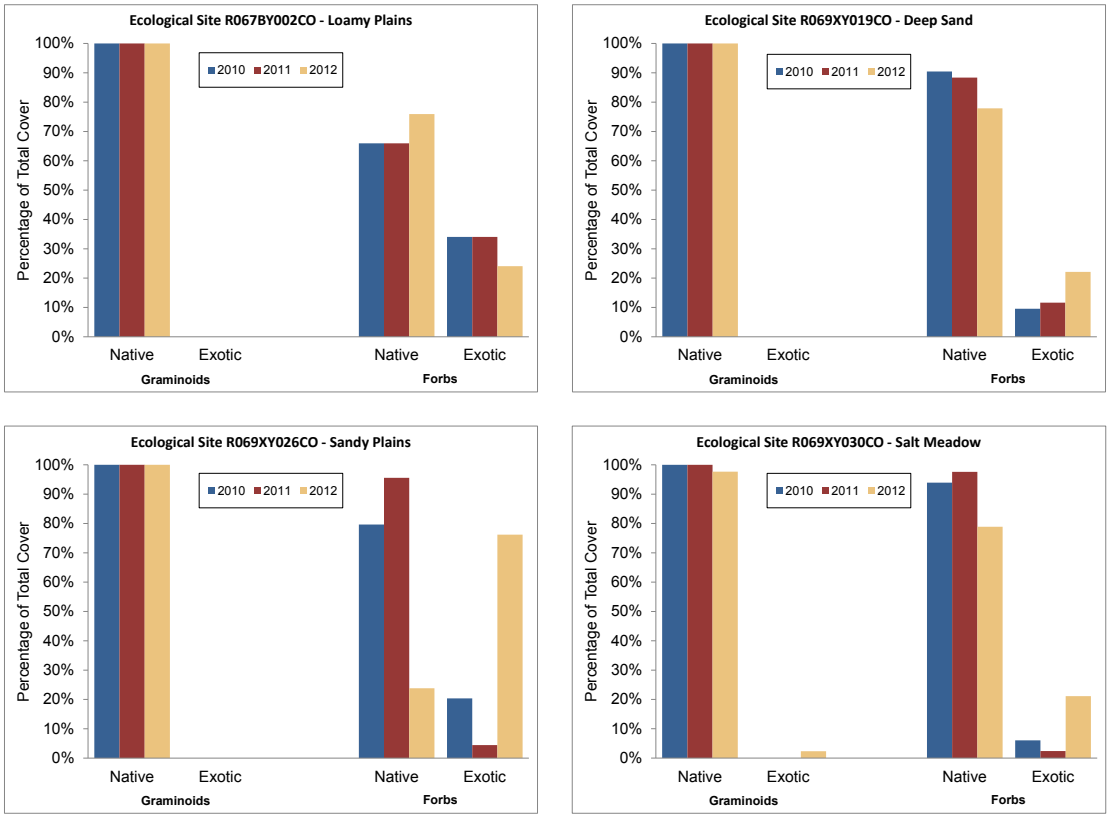


Figure 4.9.4-2. The percentage of native and exotic grasses and forbs for each ecological site samples in 2010-2012 at Sand Creek Massacre NHS.

These results are based on grassland monitoring plots, which are located throughout the Historic Site. Two additional sources of information about exotics are the SOPN exotic monitoring transects and a supplementary rapid assessment grid that was sampled in 2011. Both of these sources of information are presented in depth in Chapter 4.11. However, both of these sources of data focused explicitly and exclusively on exotic species in order to gain a better understanding of their distribution and density; thus do not consider how prevalent these exotics are relative to native species. The SOPN exotic monitoring transects focus explicitly on areas considered as high risk for invasion of exotics; thus are not representative of grasslands in general. The supplementary rapid assessment grid covers the entirety of the Historic Site at 250 m intervals; thus does represent the overall Historic Site, but does not take into account native species.

Response of Annual Species to Disturbance

The proportion of annual, biennial and perennial species provides an indication of the stability of the site, and it is generally expected that the proportion of annual species at a given site would be higher immediately following a disturbance, but would shift toward an increased proportion of perennials as time passes since a disturbance. Data from our grassland monitoring samples indicated that grasses were nearly all perennial (Figure 4.9.4-3). Forbs were considerably more variable among sites and years, but also

Table 4.9.4-3. The number and percentage of perennial grass and forb species observed at each ecological site on Sand Creek Massacre NHS during the 2010-2012 grassland monitoring sampling. Also shown is the range of percentages reported for historic late seral plant communities in the ecological site descriptions for that site based on NRCS (2007).

Ecological Site No.	Ecological Site Name	Life Form	Percent Perennials Observed 2010-2012	Range of Percentage of Perennials derived from Ecological Site Descriptions
R067BY002CO	Loamy Plains	Graminoid	100%	98-100%
R067BY002CO	Loamy Plains	Forb	57%	50-97%
R069XY019CO	Deep Sand	Graminoid	100%	100% [1]
R069XY019CO	Deep Sand	Forb	35%	18-96%
R069XY026CO	Sandy Plains	Graminoid	100%	100%[1]
R069XY026CO	Sandy Plains	Forb	77%	26-97%
R069XY030CO	Salt Meadow	Graminoid	99%	100%[1]
R069XY030CO	Salt Meadow	Forb	43%	24-100%

[1]Based on values reported for minimum and and maximum production, no range of variation can be estimated.

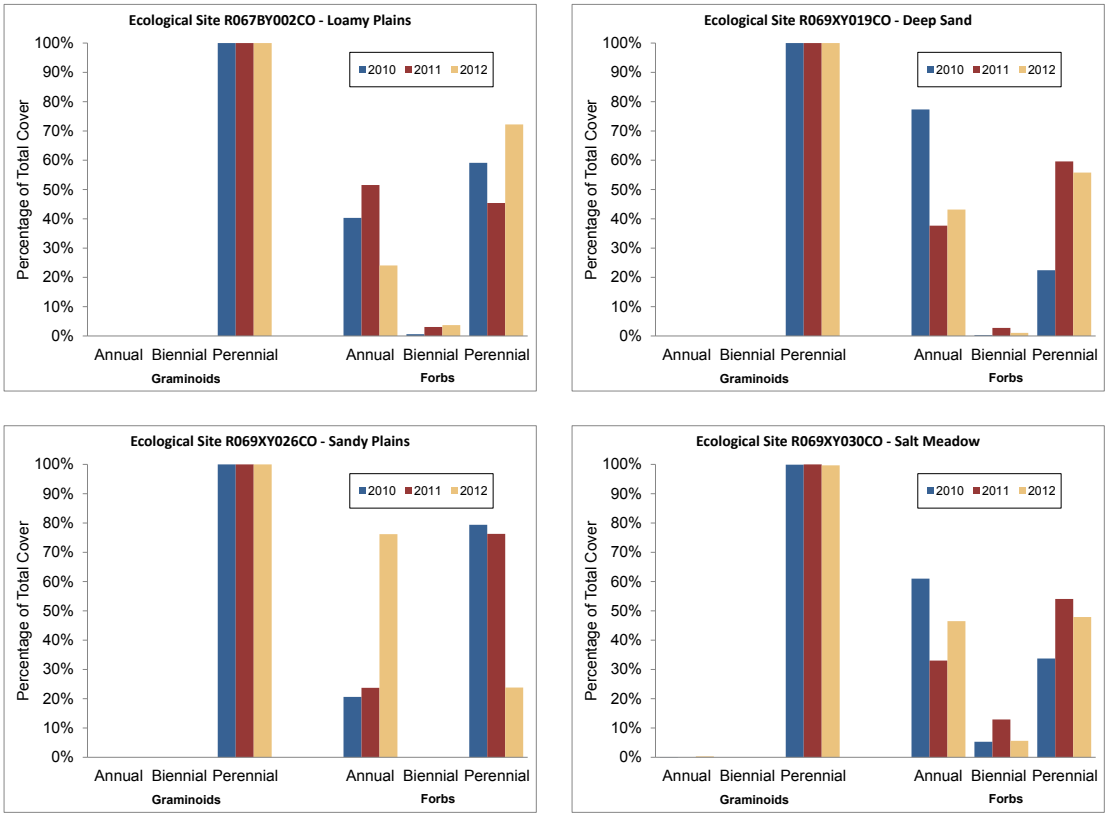


Figure 4.9.4-3. The percentage of annual, biennial, and perennial grasses and forbs for each ecological site and each years sampled at Sand Creek Massacre NHS.

tended to have a high proportion of perennial species.

Based on what is considered the historic late seral plant communities (NRCS 2007), the proportion of perennial species was generally high for grasses and more variable for forbs (Table 4.9.4-3). As previously discussed, we did not have any expectation for the proportion of annuals, biennials, and

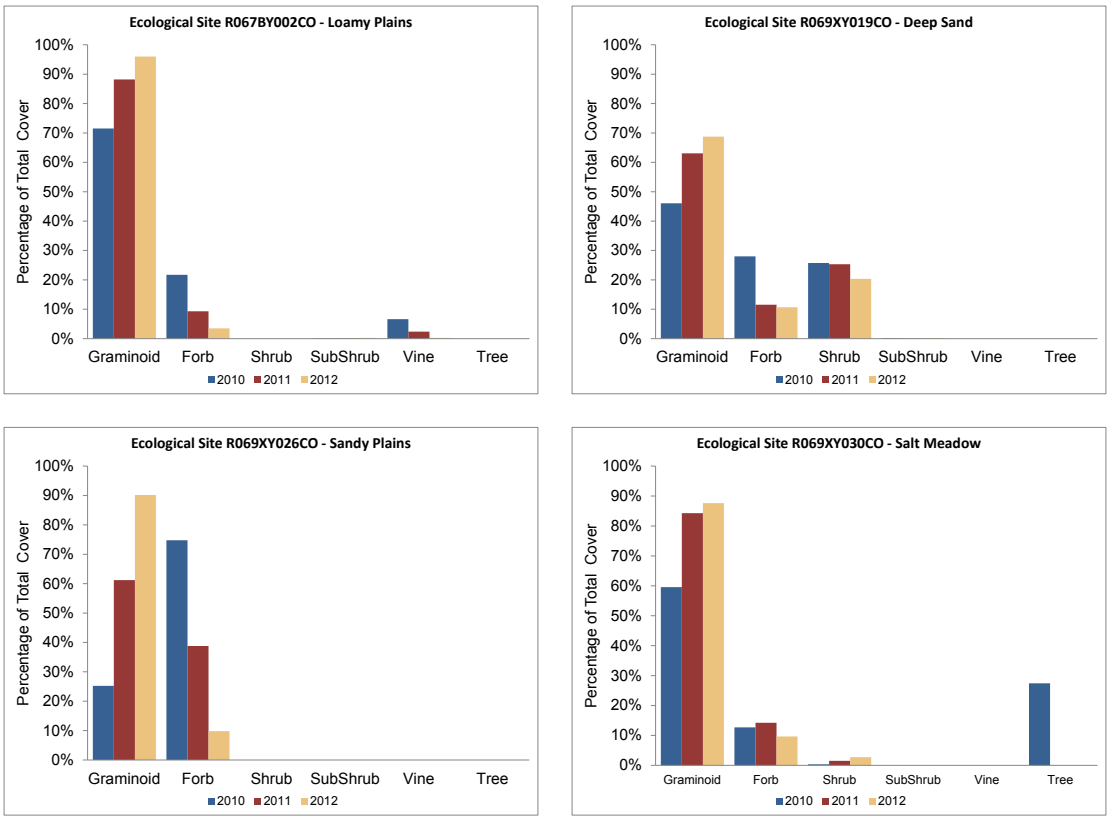


Figure 4.9.4-4. The percentage of life forms for each ecological site samples in 2010-2012 at Sand Creek Massacre NHS.

perennials, to coincide exactly with historic late seral plant communities, in part because of local site variability and not all sites are at a late seral stage. At Sand Creek Massacre NHS, sites that exhibited relatively low proportion of perennials were sites that have experienced disturbance from prairie dog colonies and more pronounced response to recent drought.. Thus, it is not surprising that we observe a higher proportion of annual species on these sites. The time frames over which we might expect a shift toward increasing perennial species probably depends on the type, intensity and duration of the disturbance.

During the rapid assessment, the proportion of annual, biennial and perennial species was discussed as a potential indicator of grassland condition; but no concern was expressed over the current condition. Areas disturbed by prairie dog activity or historic agriculture (CRP Lands) are anticipated to require a long time to recover to native prairie and should probably be monitored, but do not warrant immediate concern. Thus, we considered Sand Creek Massacre NHS to be in good condition overall with respect to this indicator.

Relative Proportion of Functional Groups - The proportions of functional groups observed in our grassland monitoring did not entirely match those reported for HCPCs in the ecological site descriptions (Table 4.9.4-4) and showed some annual variability among years (Figure 4.9.4-4). However, for reasons previously discussed, this was not of particular concern. Additionally, during the rapid assessment, the subject experts found no major concerns regarding the proportion of the various life forms. Sand sage is native, but based on historic accounts, has likely increased in density, particularly on the deep sand and sandy bottomland ecological sites. The lack of fire or fire suppression is believed to have contributed to the increase of sand sage. Our monitoring data from the deep sands ecological site supports this conclusion in having the higher shrub cover compared to other sites. The grassland experts also expressed that this increased shrub density does not warrant high immediate concern, but should be monitored if conversion from

Table 4.9.4-4. The number and percentage cover of each life form observed at each ecological site on Sand Creek Massacre NHS during the 2010-2012 grassland monitoring sampling. Also shown is the potential range of percentages reported for historic late seral plant communities in the ecological site descriptions for that site based on NRCS (2007a,b).

Ecological Site No.	Ecological Site Name	Life Form	Percent Observed 2010-2012	Range of Percentages of each life for reported in Ecological Site Descriptions
R067BY002CO	Loamy Plains	Grass/Grass-like	84%	70-85%
R067BY002CO	Loamy Plains	Forb	13%	5-15%
R067BY002CO	Loamy Plains	Shrub	0%	10-15%
R067BY002CO	Loamy Plains	Subshrub	<1%	--[1]
R067BY002CO	Loamy Plains	Vine	3%	--[1]
R067BY002CO	Loamy Plains	Tree	0%	--[1]
R069XY019CO	Deep Sand	Grass/Grass-like	57%	70-85%
R069XY019CO	Deep Sand	Forb	18%	10-15%
R069XY019CO	Deep Sand	Shrub	24%	5-15%
R069XY019CO	Deep Sand	Subshrub	<1%	--[1]
R069XY019CO	Deep Sand	Vine	0%	--[1]
R069XY019CO	Deep Sand	Tree	0%	--[1]
R069XY026CO	Sandy Plains	Grass/Grass-like	49%	70-85%
R069XY026CO	Sandy Plains	Forb	51%	10-15%
R069XY026CO	Sandy Plains	Shrub	0%	5-15%
R069XY026CO	Sandy Plains	Subshrub	0%	--[1]
R069XY026CO	Sandy Plains	Vine	0%	--[1]
R069XY026CO	Sandy Plains	Tree	0%	--[1]
R069XY030CO	Salt Meadow	Grass/Grass-like	73%	80-95%
R069XY030CO	Salt Meadow	Forb	13%	3-10%
R069XY030CO	Salt Meadow	Shrub	1%	2-10%
R069XY030CO	Salt Meadow	Subshrub	0%	--[1]
R069XY030CO	Salt Meadow	Vine	0%	--[1]
R069XY030CO	Salt Meadow	Tree	13%	--[1]

[1] *Percentages for this life form were not reported in Ecological Site Description*

grassland to shrubland continues and is not desired.

The Historic Site has been considering various management options that might be used to control the density of shrubs. In particular, the Historic Site has experiment with mowing as a shrub management treatment (Figure 4.9.4-5). The subject experts agreed that mowing appeared to be an effective tool, but also agreed that fire would likely need to play a future role should control of shrubs be deemed necessary by the Historic Site.

Relative Proportion of C3 and C4 Species – During the rapid assessment, the subject experts found no major concern about the proportion of C3 and C4 Grasses. As is typical for short grass prairie, grassland sites at Sand Creek Massacre NHS are dominated



Figure 4.9.4-5. Site at Sand Creek Massacre NHS where mowing has been used to decrease shrub density (center and right), and areas that have not been mowed (foreground and left).

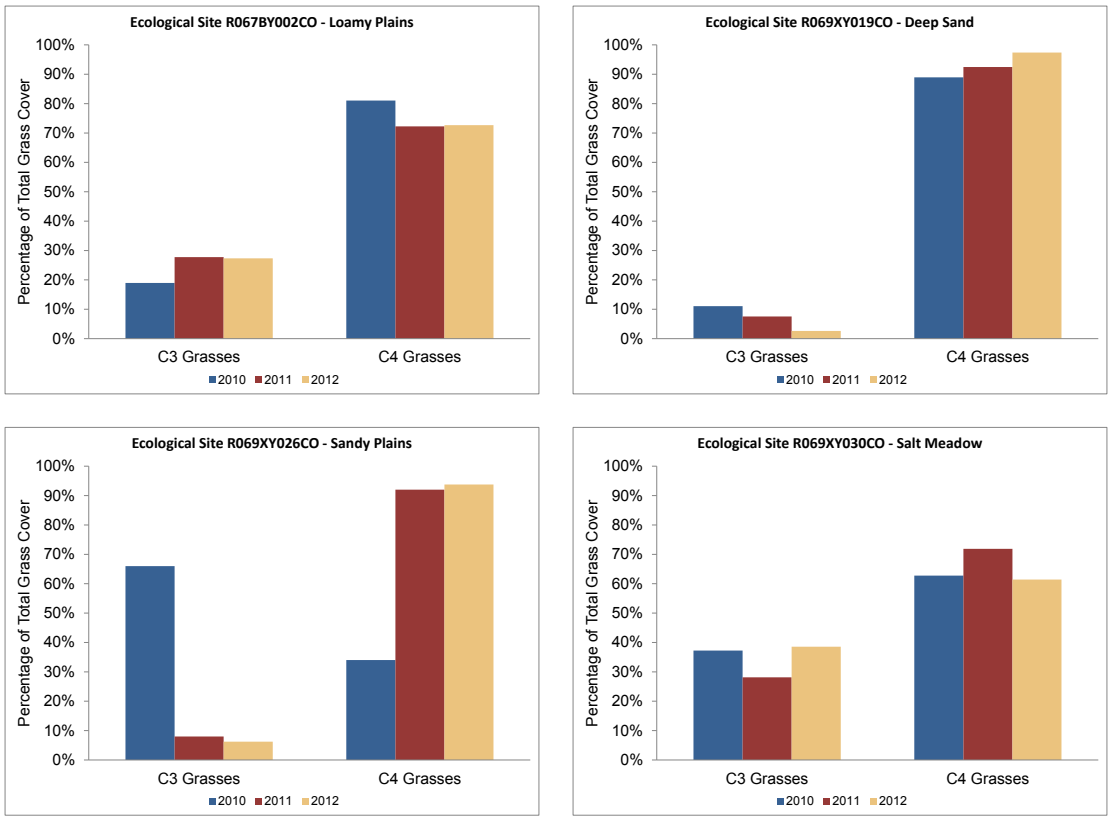


Figure 4.9.4-6. The percentage of C3 and C4 grasses for each ecological site samples in 2010-2012 at Sand Creek Massacre NHS.

by C4 grasses. Our monitoring data indicated that overall and Sand Creek Massacre NHS, C4 grasses comprised 76% of the total grass cover, and therefor C3 grasses comprised 24%. As expected, there is some variation of this among the ecological sites (Figure 4.9.4-6) (Table 4.9.4-5). This is certainly a reasonable expectation for short grass prairie in this region. Petit (1974) found 75% of the above ground biomass in a site near Amarillo Tx, to be C4 grasses, and this is also consistent with what has been observed on the Short Grass Steppe LTER site in Colorado (Lauenroth and Milchunas 1992, Lauenroth 2008). The experts did note that the area of CRP lands within the loamy plain ecological site had a

Table 4.9.4-5. The percentage of C4 vs C3 grasses observed at each ecological site on Sand Creek Massacre NHS during the 2010-2012 grassland monitoring sampling. Also shown is the range of percentages derived from ecological site descriptions for that site based on the species reported for historic late seral plant communities.

Ecological Site No.	Ecological Site Name	Percentage of C4 (vs C3) Grasses Observed 2010-2012	Range of Percentage of of C4 Grasses derived from Ecological Site Descriptions
R067BY002CO	Loamy Plains	75%	32-62%
R069XY019CO	Deep Sand	93%	83-97%
R069XY026CO	Sandy Plains	77%	84-99%
R069XY030CO	Salt Meadow	64%	48-74%

higher mix of C3 grasses, but not enough to warrant concern.

Predicted, generalized climate change impacts for this region are drier, hotter, and more severe storms (and more frequent, severe fires). Should these predictions be correct, it may favor shrub invasion and alter C4 and C3 species composition .

The Role of Fire in Grassland Condition at Sand Creek Massacre NHS

Historical records of fire frequencies for prairies of the southern Great Plains before settlement are generally nonexistent or unreliable because there are no trees to carry fire scars from which to estimate fire frequency (Ford and McPherson. 1996). Although fire is generally reported to play a prominent role in health and functioning of grasslands (e.g., Joern and Keeler 1995), this role likely varies substantially among grassland types. In particular, the role of fire as a primary determinant of grassland structure likely decreases strongly from tallgrass prairie to shortgrass steppe as a result of the gradient in productivity and fuel (Kucera 1981, Oesterheld et al. 1999, Scheintaub et al. 2009). In fact, grassland experts Drs. Alan Knapp and William Lauenroth (pers comm.) suggest that fire probably plays a much lesser role in maintaining a healthy prairie in the shortgrass steppe than other drivers such as herbivory and climate variation.

One of the perceived benefits of fire in grassland systems is the reduction of litter. In tallgrass prairie, litter removal increases soil temperature and light leading to increased productivity (Hulbert, 1988; Knapp and Seastedt, 1986). However, shortgrass steppe has minimal litter accumulation (Burke et al.,1998), and Scheintaub et al. (2009) reported a positive relationship between litter and productivity, suggesting that litter may facilitate, or at least not inhibit productivity as it does in tallgrass prairie. However, Scheintaub et al. (2009) also suggest that further research is needed on the relationship between littler and productivity in short grass steppe.

The absence of fire is also generally thought to have contributed to the increase in sand sage within the site. When fires do occur it is possible that the fuel loading is such that fires burn at a greater severity than they did historically, especially where shrubs have encroached. Should the Historic Site decide that a reduction in density of sand sage is warranted, fire is one of the likely management tools, along with mowing, that will need to be considered to achieve such a reduction. However, whether this has a positive, neutral or negative benefit on grassland condition will depend on several factors (season, frequency, potential for exotic plant response, etc) that will need to be considered carefully by the Historic Site and fire management program. The uncertainty associated with the use of fire as a vegetation management tool might also warrant that such action be undertaken under an adaptive management framework including monitoring of the response.

Table 4.9.4-6. Summary of the grassland indicators/measures categories and their contributions to the overall assessment of grassland condition.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Soil/Site Stability and Hydrologic Function (10 measures)	Soil/Site Stability and Hydrologic Function addresses capacity of an area to limit excessive loss and/or redistribution of soil resources by wind and water.	Cumulative departures from expected conditions for most measures of Soil/Site Stability and Hydrologic Function general ranged from none to slight at five of the eight sampled sites, with only three sites (usually along roads or ditches) having some measures with moderate departures.
Biotic Integrity (5 measures)	The biotic integrity addresses the capacity for the composition and functioning of the grassland communities to remain within normal range of variability expected for the site and to resist a loss in this capacity and/or to recover this capacity when losses do occur.	All measures of biotic integrity showed little departure from the range of variability that would be expected for those sites. The vast majority of species at Sand Creek Massacre NHS are native and the percent cover was dominated native species. Cover was generally dominated by native perennial c4 grasses, which is what would be expected in a healthy shortgrass prairie.

Overall Condition

For assessing the condition of grasslands, we used a variety of indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the Historic Site's grasslands. Grassland condition can be assessed from many different angles, but we chose two main categories for this resource. A summary of how they contributed to the overall grassland condition is summarized in Table 4.9.4-6. Based on the indicators, data, and expert opinion, we consider the overall condition of the grasslands at Sand Creek Massacre NHS to be in good condition with an improving trend. In Biggam's rapid assessment of the soil condition he determined the trend to be improving. In addition, lands that had been previously disturbed (e.g., CRP lands) are also slowing improving. Shortgrass prairies are typically dominated by perennial C4 grasses, which is the case at Sand Creek Massacre NHS. Although already covered in the riparian assessment, grassland areas of riparian areas are also in excellent condition. Although exotic plants are certainly present at Sand Creek Massacre NHS and are worth closely monitoring, they do not dominate the landscape as they do in many other grasslands.

The CRP areas have a bit of a departure from the historic shortgrass communities, but they too are at least functioning as healthy grasslands, and probably do not warrant much concern. Similarly, areas with previous, and possibly future, prairie dog activity represent a departure from historic late seral communities, but they are also within the realm of what would be expected on these sites based on NRCS state and transition models for areas with such disturbance.

Level of Confidence/Key Uncertainties

Overall, our confidence in this assessment is high, although as is generally the case, there are uncertainties. Some of the key uncertainties for the grassland assessment include annual variability, the effect of drought conditions, and the effect of recovery from disturbance.

Annual variability in rainfall, temperatures, diseases, etc. can have a dramatic effect on some indicators (e.g., plant species composition), which in turn, affects our interpretation of grassland condition. However, this assessment was conducted,

at least in part, during drought conditions. The stress from drought conditions has likely influenced some of our indicators, but this influence would also likely imply our assessment is a bit conservative. That is, conditions may have appeared even better had they been assessed under more typical rainfall period.

Another uncertainty is that parts of the site are changing in response to time since disturbance. CRP areas underwent major type conversion and are slowly recovering from that period. However, it will likely take decades before we fully understand the degree to which these areas might recover to their pre-disturbed. Similarly, a large prairie dog community previously existed on the site. However, the prairie dog population at Sand Creek Massacre NHS has been decimated due to plague (see chapter 4.10.12). Prairie dogs can have a dramatic effect on the grassland landscapes on which they occur. It is not known whether or not prairie dog populations will re-colonize the site and or the degree and speed of recovery should they not return.

4.9.5. Sources of Expertise

During the course of this assessment, we consulted with the following individuals who provided subject matter expertise as well as an on-site rapid assessment.

Dr. Alan K. Knapp is a Professor at Colorado State University, Department of Biology. Dr. Knapp has an extensive background of research and publications related to the ecology of grasslands.

Dr. Timothy Seastedt is a a Professor at University of Colorado, Boulder, Department of Ecology and Evolutionary Biology. He also has an extensive background of research and publications related to the ecology of grasslands.

Peter Biggam is a soil scientist at the NPS Natural Resources Program Center Geoscience and Restoration Branch., who specializes in, but also has an extensive background in range science and management. Biggam visited Sand Creek Massacre NHS as part of a rapid assessment team and the parts of this assessment related Soil/Site Stability and Hydrologic Function are based on Biggam's assessment.

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4.10. Exotic Plants

Indicators/Measures

- Significance of impact
- Feasibility of control
- Proportion of high priority blocks infested
- Proportion of park grid plots infested
- Distribution of highly ranked species

Condition – Trend – Confidence



Good – Unchanging –High

4.10.1. Background and Importance

Globalization of commerce, transportation, human migration, and recreation in recent history has introduced invasive exotic species to new areas at an unprecedented rate. Biogeographical barriers that once restricted the location and expansion of species have been circumvented, culminating in the homogenization of Earth's biota. Although only 10% of introduced species become established and only 1% become problematic (Williamson 1993; Williamson and Fitter 1996) or invasive, nonnative species have profound impacts worldwide on the environment, economies, and human health.

Invasive species have been directly linked to the replacement of dominant native species (Tilman 1999), the loss of rare species (King 1985), changes in ecosystem structure, alteration of nutrient cycles and soil chemistry (Ehrenfeld 2003), shifts in community productivity (Vitousek 1990), reduced agricultural productivity, and changes in water availability (D'Antonio and Mahall 1991). The damage caused by these species to natural resources is often irreparable, and our understanding of the consequences incomplete. Invasive species are second only to habitat destruction as a threat to wildland biodiversity (Wilcove et al. 1998). Consequently, the dynamic relationships among plants, animals, soil, and water established over many thousands of years are at risk of being destroyed in a relatively brief period. For the NPS, the consequences of these invasions present a significant challenge to the management of the agency's natural resources "unimpaired for the enjoyment of future generations." National parks, like land managed by other organizations, are deluged by new exotic species arriving through predictable (e.g., road, trail, and riparian corridors), sudden (e.g., long-distance dispersal through cargo



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Figure 4.10.1-1. Brome grasses (*Bromus arvensis* and *B. tectorum*), are invasive exotic plants found at Sand Creek Massacre NHS.

containers and air freight), and unexpected anthropogenic pathways (e.g., weed seeds in restoration planting mixes) (Figure 4.10.1-1). Nonnative plants claim an estimated 4,600 acres of public land each year in the United States (Asher and Harmon 1995), significantly altering local flora. For example, exotic plants comprise an estimated 43% and 36% of the flora of the states of Hawaii and New York, respectively (Rejmanek and Randall 1994). Invasive plants infest an estimated 2.6 million acres of the 83 million acres managed by the NPS. Prevention and early detection are the principal strategies for successful invasive exotic plant management. While there is a need for long-term suppression programs to address high-impact species, eradication efforts are most successful for infestations of less than one hectare in size (Rejmanek and Pitcairn 2002).

4.10.2. Data and Methods

In evaluating current condition and trend for exotic plants at Sand Creek Massacre NHS, five indicators/measures were considered.

Indicators/Measures

Significance of impact and
Feasibility of control

One of our first indicators for exotic plants was to determine which species pose the greatest risk to the Historic Site. As a foundation for evaluating potential risk, we used the Exotic Species Ranking System presented by Hiebert and Stubbendieck (1993) (Appendix E). This ranking system has been applied in parks throughout the Midwest (Stubbendieck et al. 1992; Stumpf et al. 1994) as well as at Sand Creek Massacre, Capulin Volcano, Washita Battlefield, and Fort Union National Monument. Ranking is based on two primary components of the potential risk: *significance of impact* and *feasibility of control/management*. Each component has several subcomponents and is ranked on a scale from 0–100 points.

Significance of impact is subdivided into the current level of impact and the potential for the species to become a pest. The current level of impact takes into account such things as abundance, distribution relative to disturbance, effects on natural processes and community character, potential threat to Historic Site resources, and visual impact. The potential for a species to become a pest considers life history traits that might preadapt a given species to become a problem as well as its known impacts in other areas. Important life history characteristics include potential rate of increase, adaptations for long-distance dispersal, and the breadth of habitats in which the species can colonize and thrive.

Feasibility of control/management focuses on things such as its abundance within the Historic Site, the ease to which the plant is controlled, its reproductive capability, proximity of other populations, potential side effects of control measures, and the potential for biological control.

Indicators/Measures

Proportion of high priority blocks (i.e., roads, trails, etc.) infested

As part of the Southern Plains Inventory and Monitoring Network (SOPN) exotic plants monitoring program, high priority vectors (e.g., roads and trails) were identified based on their potential risk for invasion by exotic plants. The highest priority vectors were surveyed in 2010-2012 (Figure 4.10.2-1), and the data were used to assess this indicator. This effort is part of a sampling scheme that uses a three-year rotating panel design, whereby a new area is surveyed each year (a panel) for three years, after which the areas surveyed are repeated. It is important to emphasize that this sampling approach does not provide a complete survey of exotic plants throughout the Historic Site; rather, it provides a repeated snapshot for a limited area with high potential (e.g., roads and trails) for new invasions.

Sampling was conducted from June to July each year. The methodology used in this monitoring is described in detail in Folts-Zettner et al. (2010). The approach is based on a generalized linear model, where 50-meter blocks on both sides of the vector (right [R] and left [L]) are surveyed from a transect running along (e.g., trails) or adjacent to

(e.g., along the mow strip of roads) the vector (Figure 4.10.2-2).

The full protocol also includes estimation of four density classes assigned to each block ranging from scattered plants to a dense matrix, as well as four distance classes used to determine the extent to which exotic plants are limited to the zone immediately adjacent to the vector. These measures provide more specific detail for the Historic Site than is warranted for this assessment, therefore, are provided along with other information in SOPN's annual reports (Folts-Zettner and Sosinski 2010, 2012 a,b).

Indicators/Measures

Proportion of park grid plots infested

In addition to the annual exotic plants monitoring, a rapid assessment was conducted in 2011 as a one time occurrence for this condition assessment to determine the presence of exotics throughout a 200m grid laid out across the entire Historic Site (Figure 4.10.2-1).

Presence and density data for these supplemental points were recorded in the same way as in our standard monitoring blocks described above, except that these points will not be included in our permanent rotating panels.

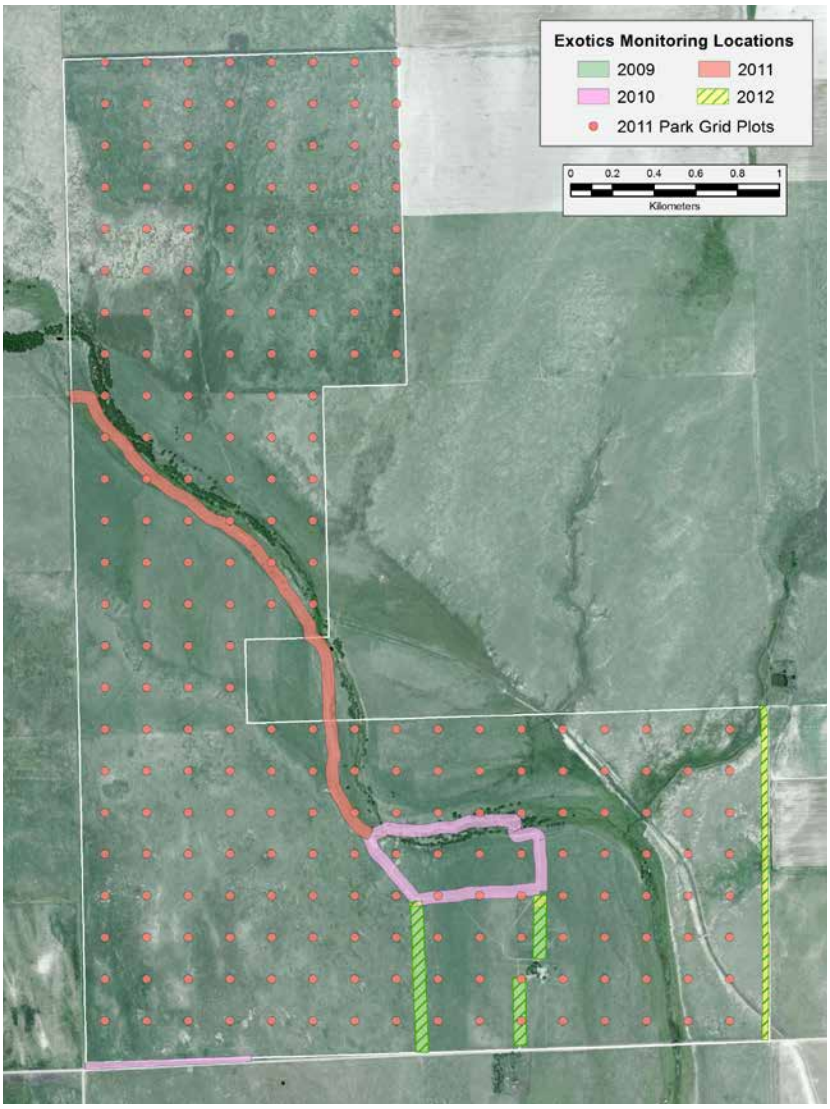


Figure 4.10.2-1. Annual high priority blocks sampled in 2010 -2012 and one time rapid assessment park grid plots sampled in 2011 only.

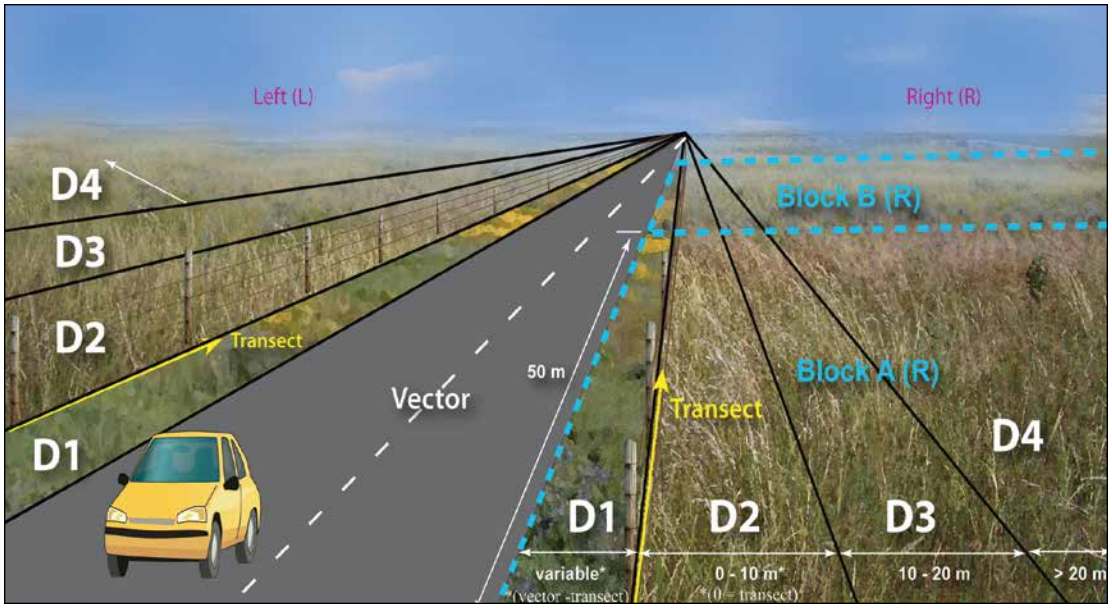


Figure 4.10.2-2. Fifty meter blocks are sampled on each side of a high-risk vector (e.g., roads and trails).

Indicators/Measures

Distribution of high priority species

For this indicator, we used data sources gathered by SOPN exotic plants monitoring efforts (Folts-Zettner and Sosinski 2012 a,b) and from SOPN and Southern Plains Fire Group grassland monitoring efforts (Folts-Zettner et al. 2012, 2013) to show the distribution of the highest ranked exotics for significance of impact.

4.10.3. Reference Conditions

The most desirable reference condition for a park is the complete absence of exotic species. However, such a reference condition is probably not a realistic standard to which exotic plant species should be compared. We consider a more realistic reference condition to be the capability for the integrity of the primary communities (e.g., woodlands, shrublands, and grasslands) to be maintained. By this, we mean that the ecological attributes (e.g., species composition, structure, etc.) and natural processes remain within the natural variation for the community type. Therefore, the reference condition of "good" is that species are known to occur regionally or on adjacent lands, but have not yet been confirmed within Historic Site, or if species have been confirmed, distribution is sparse, limited in extent, and may vary from sparse individuals to dense patches. A "moderate" condition is when species have been found in the Historic Site in small, localized patches. Finding and controlling patches might prevent large-scale invasion, and distribution is somewhat limited in extent and may vary in intensity from sparse individuals to dense patches. A condition of significant concern is warranted when exotic plants threaten to alter these primary communities to the point where they no longer maintain these attributes or processes. For example, when exotic species dominate a community where key native species are expected for that community type, then the area would be considered as severely degraded. However, significant concern is also warranted when the trend for a community is clearly toward such an degraded outcome rather than it actually having been realized.

4.10.4. Condition and Trend

There are currently 29 exotic species found within Sand Creek Massacre NHS (Table 4.10.4-1). Several additional non-native species have been cited in various species lists as occurring at the Historic Site but cannot be referenced from specific reports or were identified only to the genus level. These species are listed in a separate table in Appendix F.

Significance of Impact

Based on the ranking system of Hiebert and Stubbendiek (1993) that assesses the species innate ability to become a pest and the current level of impact at the Historic Site, field bindweed (*Convulvulus arvensis*), Kentucky bluegrass (*Poa pratensis*), Cheatgrass (*Bromus tectorum*), white/yellow sweetclover (*Melilotus alba*, *M. officinalis*), and Kochia (*Kochia scoparia*) have the highest potential impact at Sand Creek Massacre NHS (Table 4.10.4-2).

Field bindweed thrives under drought conditions, which the Historic Site has been experiencing for over the last three years. The bindweed is most often one of the only green plants observed amidst the brown dead plants (Tomye Folts-Zettner, personal communication, December 2012). There is debate as to whether *Poa pratensis* is considered to be native or non-native since it is native to the continental United States. Effects of global warming also confound debate of nativity since climate change may shift continental species (Tomye Folts-Zettner, personal communication, December 2012).

Exotic bromes are well known to dramatically change the character of an ecosystem, including such changes as major shifts in community composition and structure (Knapp 1996) as well as substantially altered fire regimes (Whisenant 1990). In many cases these changes have become, for all practical purposes, irreversible (Knapp 1996). Thus, from a standpoint of significance of impact to the Historic Site's ecosystem, we would consider the exotic brome to be a significant concern.

Table 4.10.4-1. Exotic species found within Sand Creek Massacre National Historic Site

Scientific Name	Common Name	Life Form[1]	Type[2]	Noxious[3]	Neid et al. 2007	Roath et al. 2008	SAND Plants Photos List 2008	NPS 2011	Folts-Zettner and Sosinski 2010, 2012a	Folts-Zettner and Sosinski 2012b	Folts-Zettner et al. 2012	Folts-Zettner et al. 2013	Folts-Zettner Unpublished Grid Data	Martin et al. 2012
Agropyron cristatum	Crested wheatgrass	G	P			•	•	•					•	
Amaranthus blitoides	Mat amaranth	F	A							•				
Amaranthus retroflexus	Red root amaranth	F	A				•							
Bromus arvensis	Field brome	G	A						•					
Bromus tectorum	Cheatgrass	G	A	N					•	•				
Buglossoides arvensis	Corn gromwell	F	A						•					
Chenopodium album	Common lambsquarters	F	A			•	•		•	•	•	•	•	
Cirsium vulgare	Bull thistle	F	B	N					•					
Convolvulus arvensis	Field Bindweed	V	P	N	•	•	•	•	•	•	•	•		
Elaeagnus angustifolia	Russian olive	T	P	N										•
Elymus repens	Quackgrass	G	P	N		•	•	•						
Eragrostis cilianensis	Stinkgrass	G	P							•				
Kochia scoparia (aka Bassia scoparia)	Kochia	F	A			•	•	•	•	•	•	•	•	
Lactuca serriola	Prickly lettuce	F	A/B		•	•	•	•			•			
Linaria dalmatica	Dalmation toadflax	F	P	N				•						
Linaria vulgaris	Yellow toadflax	F	P	n		•	•	•						
Medicago sativa	Alfalfa	F	A/P		•									
Melilotus alba	White sweetclover	F	A/P			•	•	•	•	•	•		•	
Melilotus officinalis	Yellow Sweetclover	F	A/P		•	•	•	•	•	•	•	•	•	
Poa pratensis	Kentucky bluegrass	G	P			•	•	•				•		
Polygonum arenastrum	Oval-leaf knotweed	F	A/P						•					
Polypogon monspeliensis	Annual rabbitsfoot grass	G	A			•	•	•						
Portulaca oleracea	Purselane	F	A			•		•						
Rumex crispus	Curley dock	F	P			•	•	•	•				•	
Salsola tragus	Prickly Russian thistle	F	A		•	•	•	•	•	•	•	•	•	
Setaria viridis	Green bristlegrass	G	A						•					
Tamarix ramosissima[4]	Saltcedar	T	P	N	•									
Tragopogon dubius	Western salsify	F	P			•	•	•	•				•	
Tribulus terrestris	Punctureveine	F	A		•									

[1] Life form: G = Graminoid, F = Forb/Herb, V = Vine, T = Tree

[2] Type: A = Annual, P = Perennial, B = Biennial

[3] Noxious: N = Listed as noxious in Colorado, n = Listed as noxious in Kansas, New Mexico, or Oklahoma (USDA NRCS 2012).

[4] Both *Tamarix ramosissima* and *Tamarix chinensis* are reported to occur at the Historic Site but it is very difficult to differentiate between them.

Table 4.10.4-2. Exotic species ranking for significance of impact at Sand Creek Massacre NHS, based on Hiebert and Stubbendieck (2003) ranking system.

Species	Significance of Impact		
	Level of Impact	Pest Potential	Total
Convolvulus arvensis	14	46	60
Poa pratensis	7	50	57
Bromus tectorum	14	41	55
Melilotus alba/ officinalis	26	29	55
Kochia scoparia	20	32	52
Salsola tragus	17	29	46
Cirsium vulgare	9	34	43
Bromus arvensis	-5	46	41
Tragopogon dubius	16	25	41
Agropyron cristatum	5	35	40
Chenopodium album	13	27	40
Lactuca serriola	6	34	40
Linaria vulgaris	-8	48	40
Tamarix ramosissima	-8	48	40
Portulaca oleracea	-8	43	35
Elaeagnus angustifolia	-8	40	32
Rumex crispus	-3	32	29
Polypogon monspeliensis	-8	36	28
Setaria viridis	-3	28	25
Polygonum arenastrum	-8	32	24
Tribulus terrestris	-8	32	24
Amaranthus retroflexus	-8	31	23
Elymus repens	-8	31	23
Medicago sativa	-8	31	23
Eragrostis cilianensis	-8	27	19
Linaria dalmatica	-8	26	18
Amaranthus blitoides	-8	24	16
Buglossoides arvensis	-8	22	14

Species ranking was conducted by Tomye Folts-Zettner of the SOPN and Kim Struthers of USU.

Currently, *Melilotus alba/officinalis* are being actively managed and are not increasing in population. Kochia grows in disturbed areas and is an indicator of changed soil chemistry, especially where organic matter has been added (i.e., barnyards, wood piles, old homestead sites). Kochia self perpetuates and continues to add organic matter into soil. It also sprouts early depending on the amount of rainfall and quickly grows and is persistent, easily outcompeting for resources.

Additional species that ranked relatively high in their significance of impact were *Salsola tragus and Cirsium vulgare*. *Salsola tragus* is drought tolerant, making 1000s of seeds annually and once dry, breaks off tumbling across the prairie dispersing its seeds. *Cirsium vulgare* is not an issue at the Historic Site, but is one that should be continuously surveyed for as it can quickly become established.

Feasibility of Control

Based on Hiebert and Stubbendieck's (2003) ranking system, *Convolvulus arvensis* ranked lowest in feasibility of control followed by *Portulaca oleracea*, *Salsola tragus*, *Agropyron cristatum, Rumex crispus*, and *Melilotus alba/officinalis.* (Table 4.10.4-3). Several traits of the species add to the difficulty of control: difficulty in detecting first-year rosettes, extensive tap root and ability to re-sprout (especially field bindweed) prodigious seed production, a long-lived seed bank (seeds remain viable in soil for many years), and widespread populations outside the Historic Site's boundary. Even though *Portulaca oleracea* is difficult to control, not many plants are growing in the Historic Site.

There are additional species, while not ranked as high as field bindweed, that should be watched closely. The sweetclovers (*Melilotus alba* and *M. officianalis*), salsify (*Tragopogon dubius*), and prickly lettuce (*Lactuca serriola*) have efficient wind-born seed distribution and are a concern because of their competitive water use in arid environments. But, overall, condition relative to feasibility of control is good.

Proportion of High Priority Blocks Infested

Salsola tragus and *Kochia scoparia* were among the most widespread within high priority areas, located along corridors such as roads and trails (Table 4.10.4-4). Both of these plants thrive in highly disturbed areas, which supports the fact that they are found along the roads and trails more often than in the interior areas of the Historic Site. In addition,

Table 4.10.4-3. Exotic species ranking for feasibility of control, from least to most feasible, at Sand Creek Massacre NHS, based on Hiebert and Stubbendieck (2003) ranking system.

Species	Feasibility of Control
Convolvulus arvensis	15
Portulaca oleracea	21
Salsola tragus	23
Agropyron cristatum	23
Rumex crispus	25
Melilotus alba/officinalis	26
Setaria viridis	30
Amaranthus blitoides	30
Bromus tectorum	31
Tragopogon dubius	34
Kochia scoparia	35
Elaeagnus angustifolia	35
Linaria vulgaris	36
Linaria dalmatica	37
Bromus arvensis	40
Polypogon monspeliensis	40
Eragrostis cilianensis	40
Poa pratensis	41
Cirsium vulgare	41
Amaranthus retroflexus	45
Buglossoides arvensis	45
Tamarix ramosissima	46
Elymus repens	46
Lactuca serriola	47
Tribulus terrestris	50
Chenopodium album	54
Polygonum arenastrum	60
Medicago sativa	60

Note: The six species ranked highest for significance of impact are shown by shaded cells for reference.

Species ranking was conducted by Tomye Folts-Zettner of the SOPN and Kim Struthers of USU.

they both thrive in drought conditions, annually producing many seeds that break off and disperse across the prairie. The next highest percentage of plants found included *Chenopodium album* and *Tragopogon dubius* at 24% and almost 20%, respectively. *Tragopogon dubius* is increasing at the Historic Site, although is still hasn't become established. There is debate as to whether *Chenopodium album* is native or non-native. There are many native *Chenopodiums* at the Historic Site, and they are very difficult to tell apart; only morphological features distinguish them, therefore, is not necessarily considered to be much of a concern (Tomye Folts-Zettner, personal communication, December 2012).

Table 4.10.4-4. Number and percentage of exotic plant species detected in high priority blocks sampled in 2010 -2012 at Sand Creek Massacre NHS.

Species	Standardized Blocks	
	No. Blocks	% (N=318)
Salsola tragus	178	55.97
Kochia scoparia	157	49.37
Chenopodium album	77	24.21
Tragopogon dubius	63	19.81
Melilotus officinalis	21	6.60
Melilotus alba	9	2.83
Convolvulus arvensis	4	1.26
Bromus tectorum	3	0.94
Cirsium vulgare	3	0.94
Eragrostis cilianensis	2	0.63
Amaranthus blitoides	1	0.31
Rumex crispus	1	0.31

Proportion of Park Grid Plots Infested

The relative order of plants found in the park grid plots were similar to the high priority blocks except with one very notable exception. *In over half of the plots sampled (57%), no exotic species were found.* This is very encouraging and a testament to the high quality efforts of staff in identifying and controlling exotics throughout the Historic Site.

Of the highest percentage of species found, both *Kochia scoparia* and *Salsola tragus* are the top two at 26% and 23%, respectively, but occur far less throughout the interior plots compared to the high priority areas (Table 4.10.4-5). These exotics have yet to invade the less disturbed sites, and the more resilient the prairie, the less likely for invasion.

Table 4.10.4-5. Number and percentage of exotic plant species detected throughout the park grid plots sampled in 2011 only at Sand Creek Massacre NHS.

Species	No. Blocks	% (N=234)
None	134	57.26
Kochia scoparia	61	26.07
Salsola tragus	54	23.08
Chenopodium album	17	7.26
Meilotus officinalis	8	3.42
Agropyron cristatum	6	2.56
Tragopogon dubius	1	0.43
Melilotus alba	1	0.43
Rumex crispus	1	0.43

Notes: Four of the six species ranked highest for significance of impact are shown by shaded cells for reference.

However, the drought conditions increase the likelihood.

Distribution of High Priority Species

The known distribution of the six highest ranked exotic plant species are shown below (Figures 4.10.4-1, -2, -3, -4, -5). Distributions of the remaining species are presented in Appendix G. Field bindweed is of a high concern because it is an aggressive competitor that can invade even an unstressed (i.e., drought) habitat. In addition, it thrives under drought conditions making it that much more significant in potential impact. It is also worth noting that the distribution of exotic bromes is not known to be widespread within the Historic Site, but is on the surrounding landscape (Tomye Folts-Zettner, personal communication, December 2012). *Bromus tectorum* is moving in from county roadsides along the Historic Site's southern boundary and first 200 meters of the entrance road (Tomye Folts-Zettner, personal communication, December 2012). Historic Site staff are currently working with county staff to implement control measures along the roadsides, but the nature of its origin presents an ongoing problem. Even though the exotic bromes have a high potential for invasion, the more robust grasslands can repel these invasions. However, this is not currently the situation with the current drought conditions.

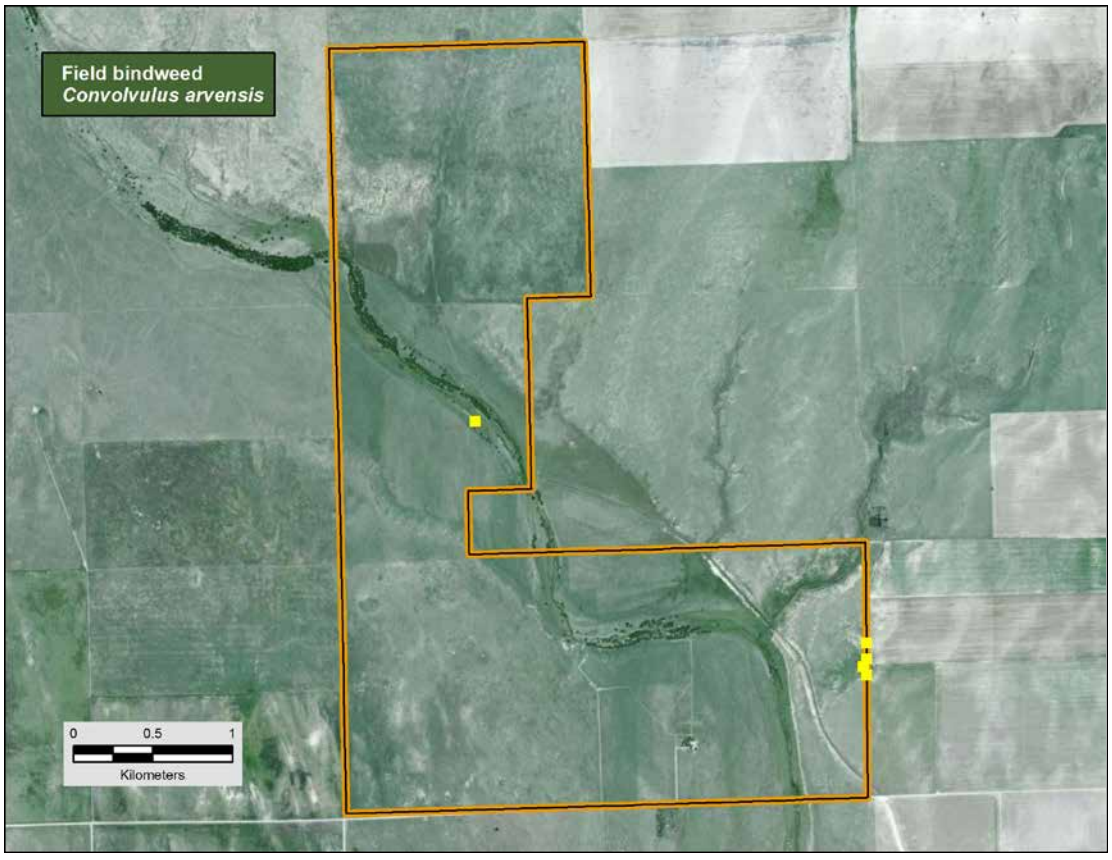


Figure 4.10.4-1. Known distribution of *Convolvulus arvensis* based on surveys conducted by SOPN and grassland monitoring efforts.

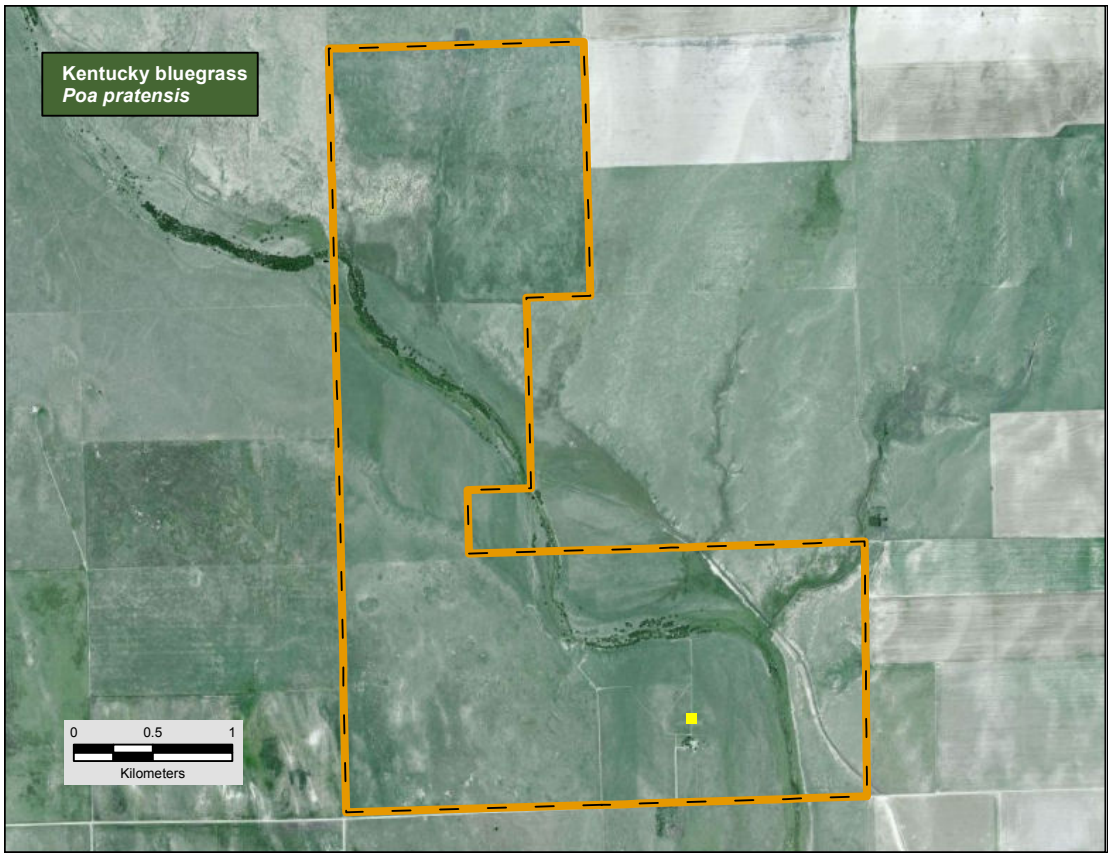


Figure 4.10.4-2. Known distribution of ecologically similar *Poa pratensis* based on surveys conducted by SOPN and grassland monitoring efforts.

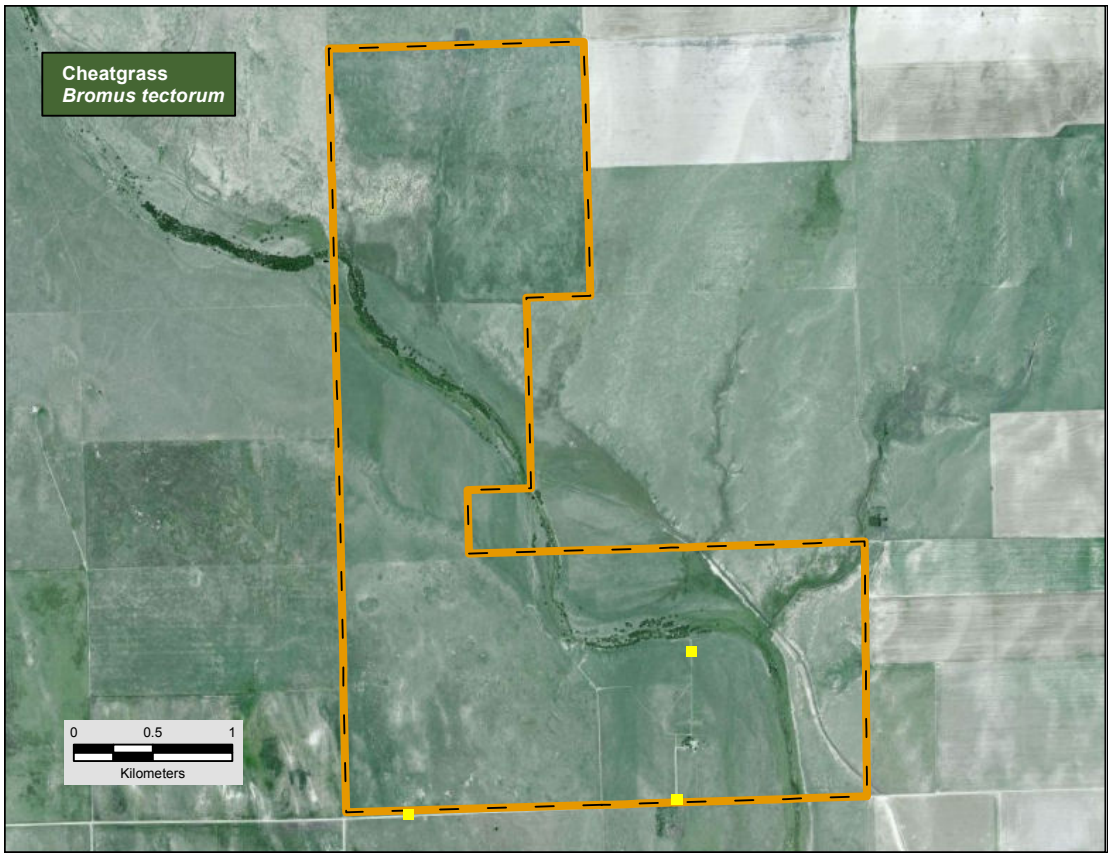


Figure 4.10.4-3. Known distribution of ecologically similar *Bromus tectorum* based on surveys conducted by SOPN and grassland monitoring efforts.

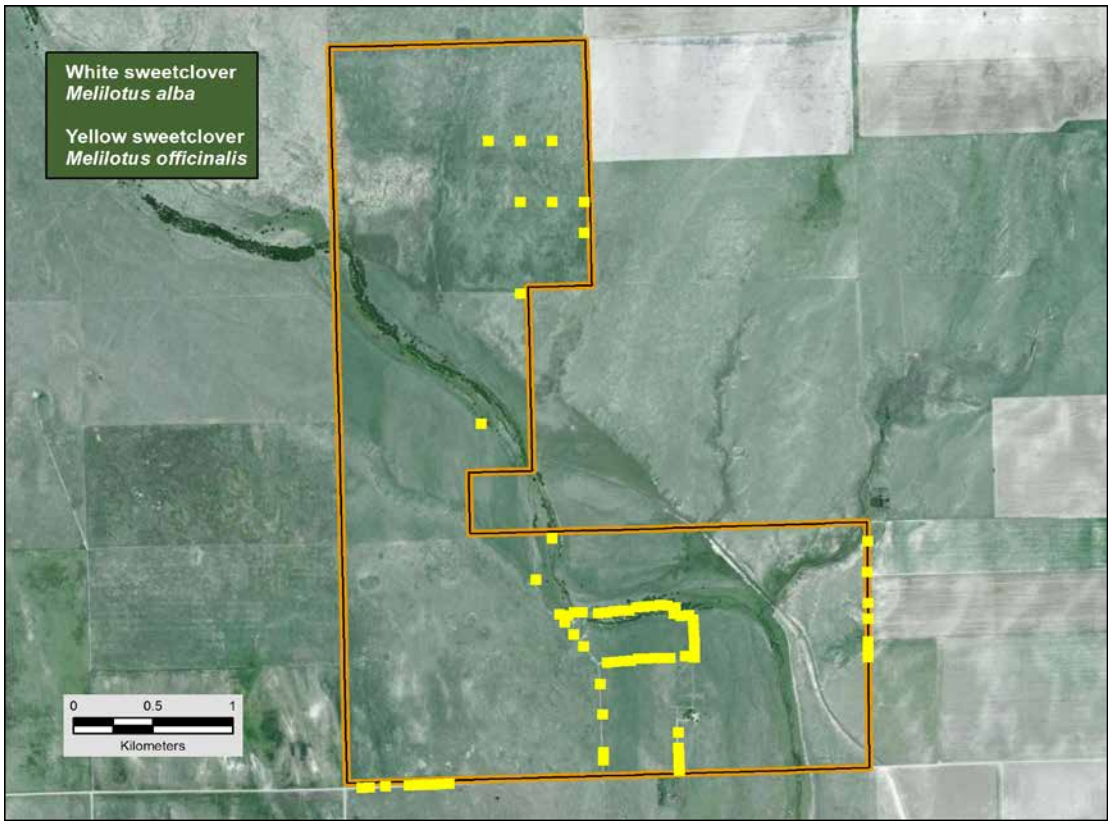


Figure 4.10.4-4. Known distribution of ecologically similar *Melilotus alba* and *M. officinalis* based on surveys conducted by SOPN and grassland monitoring efforts.

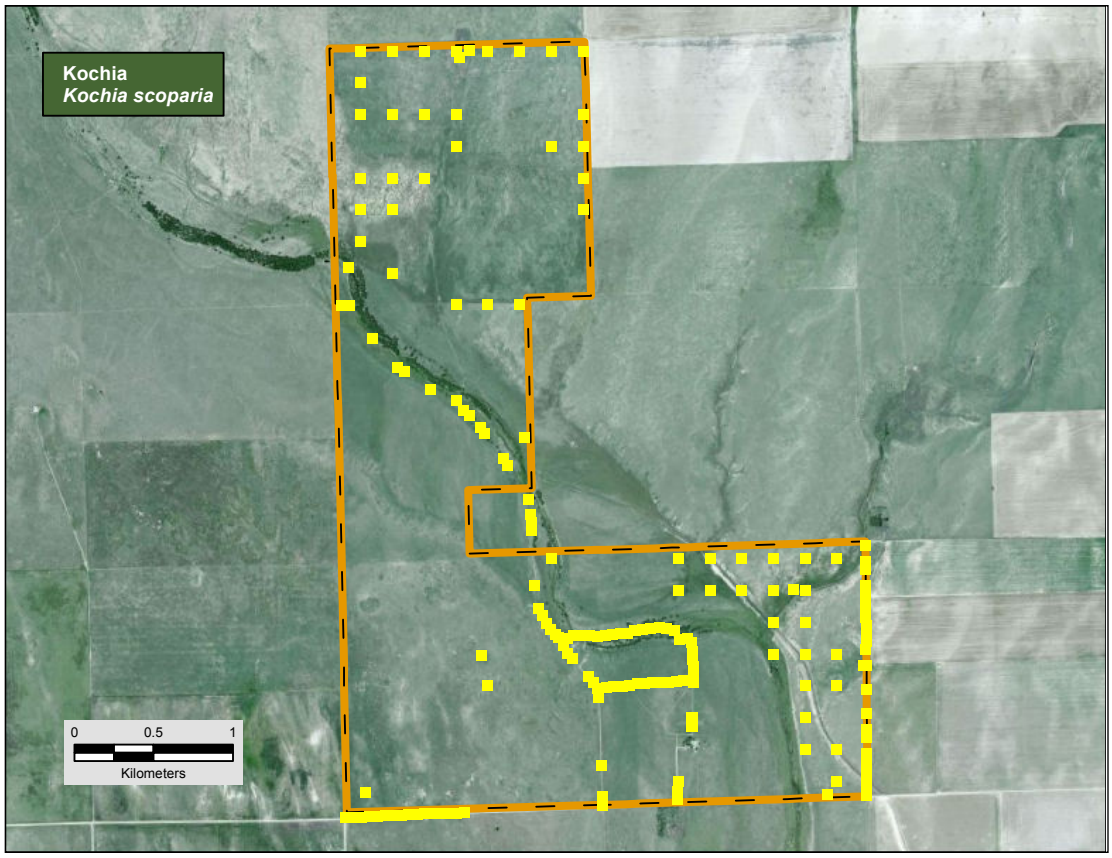


Figure 4.10.4-5. Known distribution of *Kochia scoparia* based on surveys conducted by SOPN and grassland monitoring efforts.

Table 4.10.4-6. Summary of the exotic plants indicators/measures and their contributions to the overall exotic plants natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Significance of impact	Not all exotics are the same and as such need to be assessed individually from the perspective of which ones pose the greatest risk to a given ecosystem. Significance of impact is divided into two categories, with one assessing the current status of a given exotic relative to abundance and current level of distribution and the other category assessing the potential of impact given the exotic plant's life history characteristics.	Ranking the highest in significance of impact were the field bindweed, Kentucky bluegrass, cheatgrass, and yellow/white sweetclovers. Cheatgrass is well known for its ability to dramatically change an ecosystem sometimes irreversibly. Field bindweed is an aggressive competitor, especially during dry conditions.
Feasibility of control	Given the fact that exotic plants vary in their life histories, the feasibility of controlling a particular exotic plant depends upon factors such as its current abundance, ease of control, proximity to other known populations, side effects of control measures, and response(s) to biological control.	A variety of species ranked highly infeasible to control including field bindweed, prickly Russian thistle, yellow/white sweetclovers, however, this indicator may not reflect the effort needed for control. For example, field bindweed is for the most part isolated to growing along the shoulders of the roads throughout the historic, making it easier to control.
Proportion of high priority blocks infested	High priority blocks were established by SOPN as the "well traveled vectors" where the potential for plant introduction and/or dispersal is high, such as along roads and trails. These blocks are divided into four density classes as well as four distance classes to determine the extent of exotic plant infestation.	The prickly Russian thistle and Kochia were by far the most widespread throughout the high priority blocks, with 56% and 49% detection rates, respectively.
Proportion of park grid blocks infested	Interior monitoring blocks were established throughout the Historic Site as an extra effort for this condition assessment. The park grid blocks represent other locations throughout the entire park in addition to some sites within the high priority blocks. As a result, this may be a better indicator of plant establishment versus introduction.	More than half (57%) of the blocks were not infested by any exotic! Of the exotics detected, Kochia and prickly Russian thistle were the highest at 26% and 23%, respectively, indicating that they may be more confined to the road and trail corridors.
Distribution of highly ranked species	Data from all available sources, including the interior and high priority blocks were used to map the distribution of the high priority species from the perspective of their impact, feasibility of control, and current locations.	Known distributions of the highest ranked species were mapped. Overall, the sweetclovers and kochia appear to be the most widely distributed throughout the Historic Site.

Overall Condition

For assessing the condition of exotic plants, we used five indicators/measures that were not mutually exclusive but were intended to be different ways of capturing the essence of what we thought represented the condition of the Historic Site's exotic plants. Several factors contribute to an exotic's threat to the integrity of a native ecosystem including its current status and potential for invasion based upon its life history. Also, the location where an exotic is found has implications pertaining to its establishment and potential control measures. Thus, our indicators/measures for this resource were intended to capture different aspects of these contributing factors, and a summary of how they contributed to the overall exotic plants condition is summarized in Table 4.10.4-6. Based on a qualitative evaluation of condition findings across the five indicators/measures, we consider the overall conditions for exotic plants at Sand Creek Massacre NHS to be good with a stable trend.

Level of Confidence/Key Uncertainties

The exotic plants monitoring program is designed to occur during a time of year when

early spring plants are still identifiable and rosettes are present for fall blooming plants. This strategic timing ensures the highest degree of detection. In addition with the three year rotation cycle, SOPN staff feel confident that they will identify new plants before they become established even if the plant is introduced right after the rotation cycle has been completed.

Another area of confidence is that the high priority areas that are monitored by SOPN are also the areas that Sand Creek Massacre staff frequently use throughout the spring, summer, and fall months. The staff are very vigilant with their exotic plant monitoring and control efforts and will often send images of plants for identification several times throughout the growing season (Tomye Folts-Zettner, personal communication, December 2012).

The species ranking approach developed by Hiebert and Stubbendieck (1993) does an excellent job of defining the criteria by which individual species are ranked in terms of the significance of impact and feasibility of control. However, as for any ranking system, there is also a certain degree of subjectivity that goes into any such system. Despite this potential for subjectivity, we believe that the overall ranking did reflect at least the top species of concern.

Overall, we are very confident that at least 85-90% of the exotic plants have been identified throughout the Historic Site.

4.10.5. Sources of Expertise

Surveys for exotic plants at Sand Creek Massacre NHS were conducted by the SOPN exotic plants monitoring team well trained in species identification and methods. Our confidence is very high regarding the reliability of their surveys.

Tomye Folts-Zettner is a biologist/botanist with the SOPN and is also the project lead for monitoring exotic plants in parks of the SOPN

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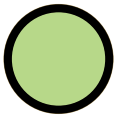
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4.11. Landbirds

Indicators/Measures

- Species Occurrence
  - Temporal Context
  - Spatial Context
  - Conservation Context

Condition - Trend - Confidence



Good - Insufficient Data - High

4.11.1. Background and Importance

The National Park Service's mission is to manage park resources "unimpaired for future generations." Protecting and managing some of our nation's most significant natural resources requires basic knowledge of the condition of ecosystems and species that occur in national parks. Landbirds are a conspicuous component of many ecosystems (Figure 4.11.1-1) and have high body temperatures, rapid metabolisms, and occupy high trophic levels. As such, changes in landbird populations may be indicators of changes in the biotic or abiotic components of the environment upon which they depend (Canterbury et al. 2000; Bryce et al. 2002). Relative to other vertebrates, landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000; Buckland et al. 2001).

Changes in landbird population and community parameters can be an important element of a comprehensive, long-term monitoring program, such as that being implemented for the SOPN parks. Birds select habitat based on the presence of behavioral cues triggered by the environment (Hutto 1985; Alcock 2005). In some environments, however, especially those that vary unpredictably, habitat may not be saturated and changes in resources may not always be tracked by changes in animal populations (Wiens 1985). In these situations, relating changes in bird populations to environmental features can be complex, especially when confounded by time lags that are characteristic of site-tenacious bird species. Additional



ROBERT SHANTZ

Figure 4.11.1-1
Horned Lark

complications occur if birds respond more sensitively to environmental change than we can detect and when cyclical environmental changes result in erratic changes in population size that are ultimately inconsequential. However, the utility of monitoring landbirds is strengthened by concurrent monitoring of a broad suite of environmental parameters (Dale and Beyeler 2001) that may assist with elucidating changes in the bird community to other environmental factors. Such a broad-based approach is now being undertaken by the SOPN program (NPS 2008) and other monitoring approaches (e.g., Ringold et al. 1996; Stevens and Gold 2003; Barrows et al. 2005).

Perhaps the most compelling reason to monitor landbird communities in SOPN parks is that birds themselves are inherently valuable. The high aesthetic and spiritual values that humans place on native wildlife is acknowledged in the agency's Organic Act: "to conserve . . . the wildlife therein . . . unimpaired for the enjoyment of future generations." Bird watching, in particular, is a popular, longstanding recreational pastime in the United States and forms the basis of a large and sustainable industry (Sekercioglu 2002).

4.11.2. Data and Methods

In 2009, Rocky Mountain Bird Observatory (RMBO) began systematic surveys of birds at Sand Creek Massacre NHS as part of the SOPN Monitoring program. Although these data will enable quantitative evaluation of trends in birds in the future (e.g., in occupancy), it is premature to use them in such a context at the present with only four years of data. Rather, for this assessment, we focus on species occurrence (presence/absence), focusing on what species are, or are not, observed at Sand Creek Massacre NHS. The most recent data we have for occurrence of birds at the Historic Site are the RMBO surveys. With the use of additional data sources, we evaluated species occurrence in three contexts: (1) a temporal context (i.e., changes over time), (2) a spatial context (i.e., comparison with surrounding region), and (3) a conservation context (i.e., the occurrence and status of species of conservation concern). We describe each of these below, followed by descriptions of the data sources used to support the comparisons.

Indicators/Measures

Species Occurrence

Temporal Context – Changes over Time

To evaluate birds in a temporal context, we compared the occurrence of species detected during 2009-2012 RMBO surveys at Sand Creek Massacre NHS (described below) to a 2005 RMBO species list (described below) of birds at the Historic Site. This analysis compares information from 2005 to 2009-2012- a time span of only four to seven years. Unfortunately, this is the best available information we have because the Historic Site is a relatively new park unit.

Our analysis is not intended as a rigorous or quantitative comparison given the limitations of such information; rather, it is intended as a crude qualitative indicator of major changes over time. However, to do this in a more meaningful way, we needed the sources to be comparable. For example, the recent RMBO surveys were conducted during the breeding season; thus it is not reasonable to compare these results with species that occur at the Historic Site during other seasons. The 2005 RMBO species list was also based on inventories during the breeding season. Still, we focused our comparisons on those species for which Sand Creek Massacre NHS is within their normal breeding range. We made this determination based primarily on the Birds of North America (BNA) species accounts (Cornell Lab of Ornithology 2012). Given the potential for us to have made errors in determining whether the Historic Site was within the normal breeding range from online and hard copy maps (GIS data were not available), we included for consideration species outside of their breeding range but within 100 miles of their breeding range edge. Unlike field guides that are often written by persons with general knowledge of birds, the BNA accounts for each species are written by persons that have extensive experience and knowledge working with that particular species. Consequently, these accounts constitute a comprehensive summary of

Table 4.11.2-1. Breeding habitat classes assigned to each species that has been reported to occur at Sand Creek Massacre NHS and is within or near its reported breeding range.

Breeding Habitat Class	Class Description
Exists	This class was assigned when the habitat at the Historic Site is characteristic of habitats where a given species might be expected to breed.
Possibly Exists	This class was assigned when it was unlikely that the habitat at the Historic Site would support consistent or widespread breeding, but does not preclude some breeding in limited numbers.
Limited to None	This class was assigned when it is unlikely that the habitat at Sand Creek Massacre NHS would support breeding by that species. This does not imply that the species would not occur at the Historic Site in limited numbers or during other seasons, but rather that it would be unlikely to breed there.

our current knowledge for a given species (including range) written by experts for that species. Note that by "normal breeding range" we mean the area designated by the BNA accounts where a species is known to consistently breed. Some birds may breed in small numbers outside of these areas, however.

We further refined our comparisons to species for which reasonably suitable breeding habitat exists at the Historic Site (since comparisons are based on the breeding season). We assigned each species to one of three breeding habitat classes (Table 4.11.2-1) based on the BNA accounts in combination with local knowledge.

Spatial Context – Comparisons with Surrounding Region

We also evaluated species occurrence in a spatial context. Again, this is intended only as a qualitative indicator rather than a rigorous quantitate estimate (which will be possible in the future). For this assessment, we compared the recent RMBO surveys at the Historic Site to regional surveys (described below) conducted by RMBO in similar habitats within the surrounding area; the regional surveys serve as a general spatial reference for species occurrence within the region. As with the temporal comparison, we focused our comparisons on those species for which the Historic Site is within their normal breeding range, but we also considered species outside of but within 100 miles of their normal breeding range. We used the regional RMBO surveys for the basis of our comparison because their methods are similar to those used in the annual RMBO surveys at the Historic Site. However, we also used the Breeding Bird Surveys, described below, as supporting information for the comparison.

Conservation Context – The Occurrence and Status of Species of Conservation Concern

Our intent for this context was to determine which species that occur at Sand Creek Massacre NHS are considered species of concern at either national or local scales, to assess the current status (occurrence) of those species at the Historic Site, and to evaluate the potential for the Historic Site to play a role in the conservation of those species. For the latter, we assigned each species of conservation concern to a class representing the potential for the Historic Site to play a role in its conservation, at least during the breeding season (Table 4.11.2-2). This was based primarily on whether or not the Historic Site was within the normal breeding range of the species and the availability of breeding habitat at the Historic Site.

To develop a candidate list for species of conservation concern, we used the lists developed by several organizations. There have been a myriad of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations, such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened

Table 4.11.2-2. Classes assigned to species of concern regarding the potential for Sand Creek Massacre NHS to play a role in their conservation.

Potential for Conservation	Conservation Class Description
High	These are species for which the Historic Site is within the normal breeding range or in proximity to the edge of that range. They are also species for which we considered the Historic Site to have good breeding habitat. We assigned species to this class if we believed, based on the evidence, that the potential for breeding was good, regardless of whether they currently occur at the Historic Site in substantial numbers.
Moderate	These are the species for which the Historic Site is within the normal breeding range or in proximity to the edge of that range, and for which there is some habitat at the Historic Site that might support occurrence or even some breeding in limited numbers.
Low to None	These are the species that are either outside of their normal breeding range and/or for which the habitat at the Historic Site is unlikely to support breeding. This does not preclude limited occurrences of the species, but the potential for the Historic Site to play any significant role in the conservation of that species is very limited.

Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion, and perhaps frustration, for managers that need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, several of which are presented below, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2013). Bird Conservation Regions (BCRs) are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues (Figure 4.11.2-1). Sand Creek Massacre NHS lies within the Short Grass Prairie Unit (BCR-18) (Figure 4.11.2-2).

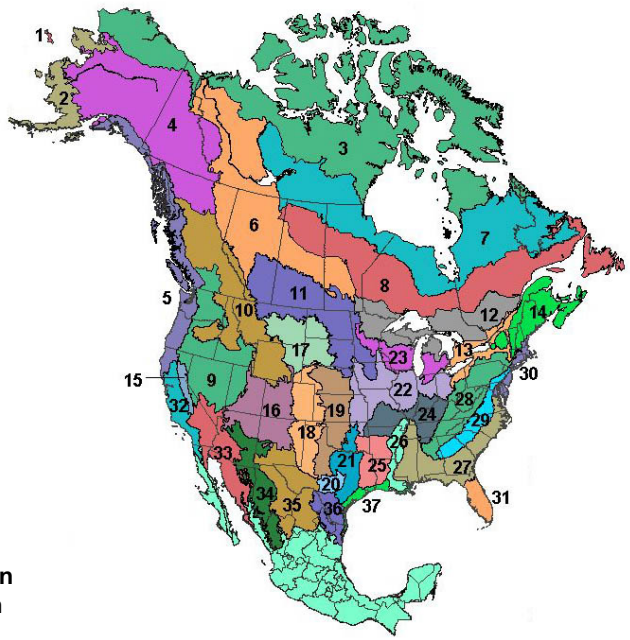


Figure 4.11.2-1. Bird Conservation Regions in North America.

Conservation Organizations Listing Species of Conservation Concern

Below we identify some of the organizations/efforts that list species of conservation concern; these are the listings we used for the condition assessment. Appendix H presents additional details on each of the organizations/efforts.

- U.S. Fish & Wildlife Service: Under the Endangered Species Act, the U.S. Fish and Wildlife Service (USFWS) lists species as threatened, endangered, or candidates for listing.
- State of Colorado: Under the authority of the Nongame, Endangered, or Threatened Species Conservation

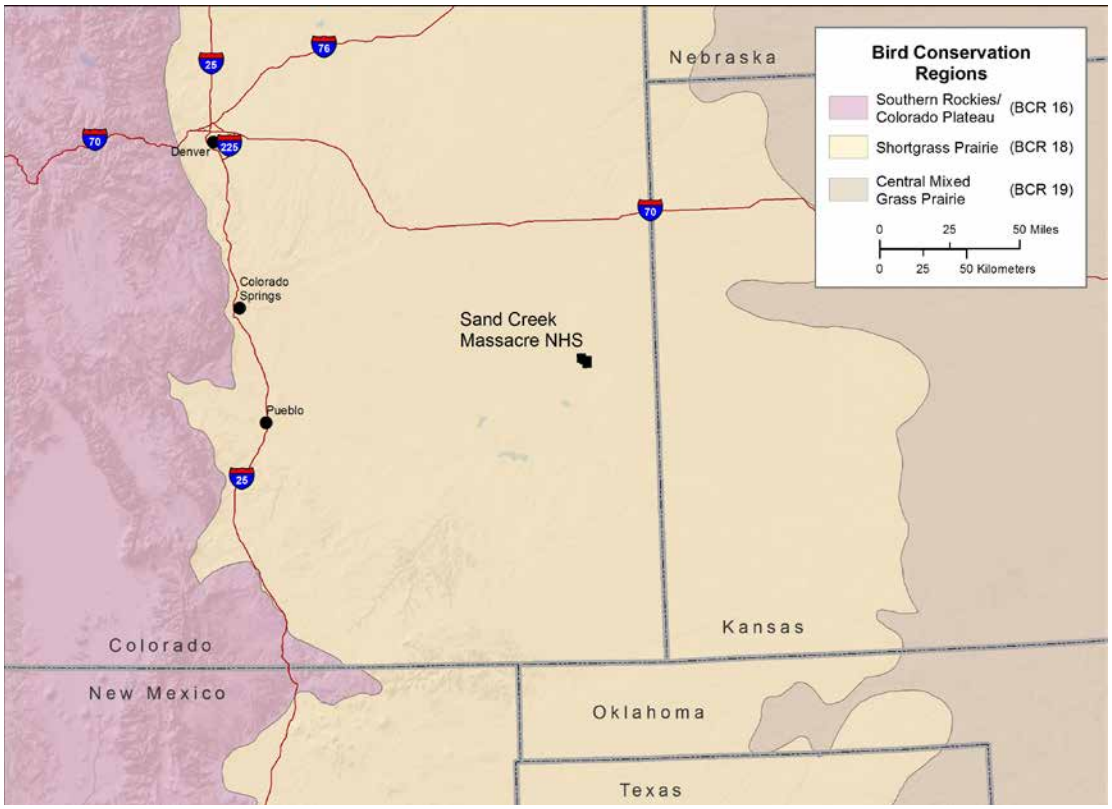


Figure 4.11.2-2. Bird Conservation Regions in the vicinity of Sand Creek Massacre NHS.

Act, the State of Colorado, through the Division of Wildlife (CDOW) (now Colorado Parks and Wildlife) maintains listings of species considered as threatened or endangered, as well as State special concern (although the latter is not a statutory category) (Colorado Parks and Wildlife 2012).

- USFWS: This agency also developed lists of birds of conservation concern according to: the Nation, USFWS Region, and BCR.
- The National Audubon Society (NAS) and American Bird Conservancy (ABC): These groups combined efforts to produce a "Watch List," based on, but not identical to, the Partners in Flight approach to species assessment (see below). The 2007 WatchList has two primary levels of concern: a "Red Watchlist," which identifies what these organizations consider as species of highest national concern; and a "Yellow WatchList," which is made up of species that are somewhat less critical.
- Partners in Flight (PIF): This is a cooperative effort among federal, state, and local government agencies, as well as private organizations. PIF has adopted BCRs as the geographic scale for updated regional bird conservation assessments. At the scale of the individual BCRs, there are species of Continental Importance (Continental Concern [CC] and Continental Stewardship [CS]) and Regional Importance (Regional Concern [RC] and Regional Stewardship [RS]).
- State of Colorado: In addition to listing threatened and endangered species, the State developed a Comprehensive Wildlife Conservation Strategy, also known as a Wildlife Action Plan (CDOW 2006) that identifies species and conservation needs for what they consider the Species of Greatest Conservation Need (SGCN). The strategy reflects a basic goal of securing wildlife populations so that they do not require protection through federal or state listing regulations (CDOW 2006).

Primary Data Sources

Data used as part of this assessment include: surveys conducted by RMBO at Sand Creek Massacre NHS, including a bird inventory and surveys in 2005 and surveys in 2009-2012; a targeted rare vertebrate species inventory in 2006 by the Colorado Natural Heritage

Program (CNHP); and surveys conducted by RMBO in the surrounding region in 2001-2005. Data were also collected from Breeding Bird Surveys (BBS), and these data were used as supporting information. Each of these is described below.

RMBO Surveys at the Historic Site in 2005

In 2005, RMBO initiated a bird inventory and monitoring protocol at Sand Creek Massacre NHS (Hanni 2005). They conducted standardized monitoring and inventory methods during the breeding season. The habitat based point-transect survey methods are described below. RMBO planned to conduct two point transects, but only one, in riparian habitat, was conducted. In addition, inventories were conducted during three separate visits in April, May, and June. The primary goal of the inventories was to determine the status of expected species that had not yet been documented. Habitats searched included wetlands, rivers, creeks, and prairie dog towns. The project recorded bird species observed, which provided an initial species list and baseline information for birds at the Historic Site.

RMBO Surveys at the Historic Site in 2009-2012

RMBO used point-transect surveys (Buckland et al. 2001) during the breeding season to estimate and monitor landbird population parameters (Lock et al. 2012). A total of about 56 points in riparian (cottonwood bottom; n=16) and grassland (shortgrass prairie; n=40) habitats were sampled 2-3 times each in 2009-2012 (Figure 4.11.2-3) (Lock et al. 2012). All birds detected at a given point were recorded. Observers spent six minutes at each point along the transect or grid and used a rangefinder to estimate the linear distance to each bird or group detected. This protocol of spending six minutes per site is consistent with other efforts being conducted by RMBO. After counts were completed, observers used a handheld GPS (Global Positioning System) unit to locate successive survey points. While walking between points, observers noted only the species that were not recorded during the count period; sometimes these represented species that had not been previously reported for the Historic Site.

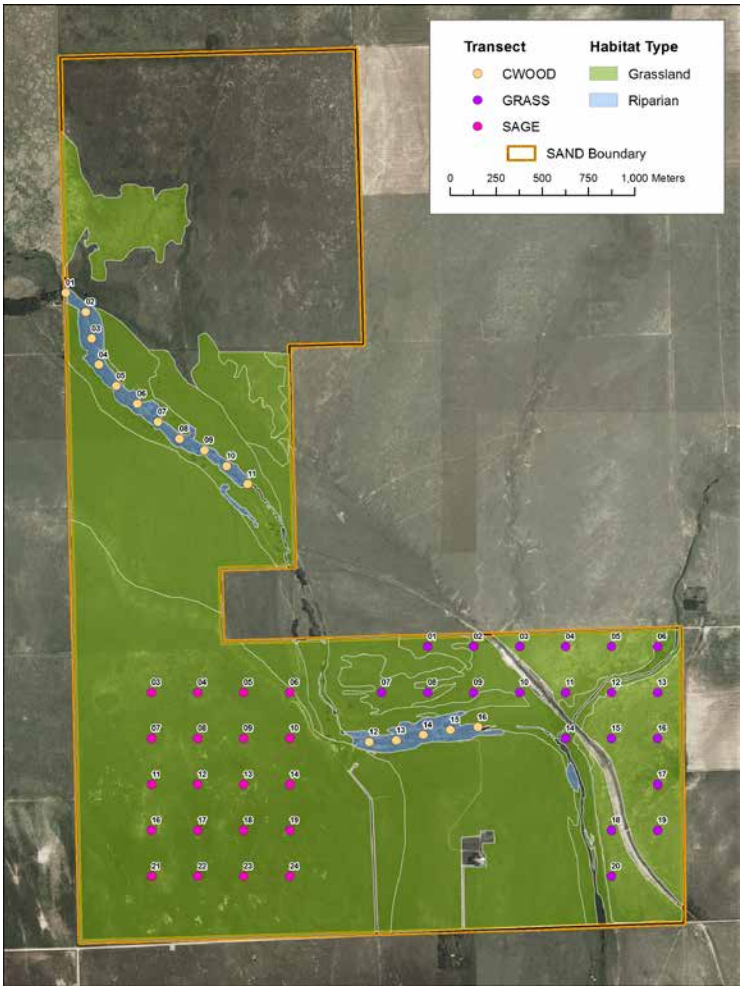


Figure 4.11.2-3. Survey points sampled by the Rocky Mountain Bird Observatory at Sand Creek Massacre NHS in 2009-2012.

Regional RMBO Surveys

Within the surrounding region, RMBO conducts additional surveys using either point based surveys (Hanni et al. 2009) or section based surveys (Sparks and Hanni 2006). The details for point-based surveys are presented in Hanni et al. (2009), but surveys consist of 15 points spaced 250 m apart, connected by a transect line. The point-transect sampling effort is stratified by habitat. The

details for section-based surveys are presented in Sparks and Hanni (2006). These surveys are a road-based point count technique with a one square mile "section" as the basic land management unit of the prairie.

Based on these regional surveys, which used road-based point counts in eastern Colorado during the breeding seasons of 2001-2005, Hanni (2005) presented a list of potential species that would be expected to be observed at the Historic Site. This list was used for the spatial comparison of bird occurrence.

CNHP Inventory
In 2006, the CNHP conducted a biological assessment of rare vertebrate species that occurred or potentially occurred at Sand Creek Massacre NHS (Sovell et al. 2008). Survey objectives for birds at the Historic Site consisted of: species specific surveys to detect the presence of Lesser-prairie Chicken; determining density and condition of Mountain Plover, Ferruginous Hawk, and Burrowing Owl populations; and recording incidental observations of other bird species that had not previously been documented at the Historic Site. The first two objectives led to reports of abundance for the target species, and the third objective produced a list of bird species observed at the Historic Site during the assessment. However, the list of birds observed from this effort is not a thorough survey comparable to those conducted by RMBO.

Although there was some overlap between sampling methods, sampling protocols in the CNHP Inventory were designed to maximize the possibility of observing each of the targeted species. For a full description of each sampling method, see Sovell et al. (2008). Surveys for Burrowing Owls, for example, consisted of walking each black-tailed prairie dog town twice. Towns were walked first in May, when owls should have established nest burrows and may have begun incubation of eggs. Towns were walked again in mid-June, when young-of-the year owls should begin to be observed above ground.

BBS Routes
Breeding bird surveys are conducted on over 4,100 survey routes located across the continental U.S. and Canada (http://www.pwrc.usgs.gov/BBS/). Each year during the height of the avian breeding season, participants skilled in avian identification sample birds along roadside survey routes. Each survey route is 24.5 miles long with stops at 0.5-mile intervals. At each stop, a 3-minute point count is conducted. During the count, every bird seen within a 0.25-mile radius or heard is recorded. Surveys start one-half hour before local sunrise and take about 5 hours to complete. There are four BBS routes in the vicinity of Sand Creek Massacre NHS; measuring from the location on the Historic Site closest to the closest point of each route, distances between the park and the survey routes range from about seven to 17 miles. We used data from BBS routes as a secondary source of information for the spatial comparison of species occurrence.

4.11.3. Reference Conditions

Temporal Reference Condition for Species Occurrence
The first bird monitoring or inventory effort at Sand Creek Massacre NHS was that made by RMBO in 2005 (i.e., Hanni 2005). During three visits to the Historic Site in April, May, and June, they detected a total of 59 species. Hanni et al. (2005) pointed out that the list was an initial one and that additional species likely occurred at the site. Also, the survey was only conducted in one habitat (riparian) along one transect due to time restrictions and adverse weather conditions, although additional inventories of upland habitat were conducted. For this reason, we also considered a small number of additional species that were detected during the 2006 CNHP inventory.

We compared the species list from the 2005 survey/inventory (and 2006 inventory) to the list of species that have been detected during the 2009-2012 RMBO surveys to see if there were any differences. Differences in the two lists may represent changes over time. Specifically, we looked at species that

Table 4.11.3-1. Reference conditions used to assess the current condition of landbird species occurrence in temporal and spatial contexts.

Occurrence Indicator	Significant Concern	Moderate Concern	Good
Temporal Context	We considered condition to be of significant concern if several species of birds that are within their normal breeding range and have existing habitat at the park were detected in the 2005-2006 surveys but not in recent RMBO surveys, particularly if those species had previously been considered common at the Historic Site.	We considered condition to be of moderate concern if a few bird species that were detected during 2005-2006 surveys that are within their normal breeding range and have breeding habitat at the park were not detected during recent RMBO surveys.	We considered condition to be good if all, or nearly all, birds that were detected during 2005-2006 surveys that are within their normal breeding range and have breeding habitat at the park were detected during recent RMBO surveys.
Spatial Context	We considered condition to be of significant concern if several species of birds that are within their normal breeding range and have breeding habitat at the Historic Site were detected during regional surveys but not during recent RMBO surveys, particularly if those species had previously been considered common at the Historic Site.	We considered condition to be of moderate concern if a few bird species that were detected during regional surveys and that are within their normal breeding range and have breeding habitat at the Historic Site were not detected during recent RMBO surveys.	We considered condition to be good if all, or nearly all, birds that were detected during regional surveys and that are within their normal breeding range and have breeding habitat at the Historic Site were detected during recent RMBO surveys.

were not observed during 2009-2012 RMBO surveys that had been documented in 2005 (and 2006). We "refined" the list of species where there were differences by excluding those species that were outside of their normal breeding range (and more than 100 miles from the edge of their normal breeding range). Although this is a crude measure and only spans a relatively short time differential, it does potentially provide some insights as to major shifts that might have occurred at the Historic Site. Table 4.11.3-1 summarizes the qualitative condition classes we assigned for the temporal and spatial indicators.

Spatial Reference Condition for Species Occurrence

In a spatial context, we compared the species observed during recent RMBO surveys (2009-2012) at Sand Creek Massacre NHS to the regional surveys in eastern Colorado conducted by RMBO (2001-2005); the regional bird list we used was presented in Appendix 2 of Hanni (2005). Both were point-count based surveys conducted during the breeding season.

Reference Condition for Species of Concern

This aspect of the assessment is somewhat different than the other two in that the focus is on the avian species for which the Historic Site can play a role in their conservation. From the list of species detected at the Historic Site during recent RMBO surveys, we identified the species that occurred on one or more of the lists of species of conservation concern. Those considered as having the greatest potential for conservation at the Historic Site are those within their breeding range and for which breeding habitat exists at the park.

4.11.4. Condition and Trend

There have been a total of 72 bird species reported at Sand Creek Massacre NHS (Appendix I). These species were detected

Table 4.11.4-1 Species reported on the 2005 RMBO survey & inventory list (and 2006 CNHP inventory) at Sand Creek Massacre NHS that were not observed during the 2009-2012 RMBO surveys. Also shown is the range status based on Birds of North America species accounts, and breeding habitat class for birds within (or within 100 miles of) their normal breeding range.

Common Name	Range Status	Breeding Habitat Class
Barn Owl	Breeding and Wintering	Possibly Exists
Blue-winged Teal	Breeding	Limited to None
Brewer's Blackbird	Outside Normal Breeding Range [1]	Limited to None
Chestnut-sided Warbler [M]	Outside Normal Breeding Range	----
Clay-colored Sparrow [M]	Outside Normal Breeding Range	----
Cliff Swallow	Breeding	Limited to None
Hermit Thrush [M]	Outside Normal Breeding Range [1]	Limited to None (None)
Indigo Bunting [M]	Outside Normal Breeding Range [1]	Limited to None
Lincoln's Sparrow [M]	Outside Normal Breeding Range	-----
Loggerhead Shrike	Breeding	Possibly Exists
Northern Harrier	Year-round	Possibly Exists
Rock Pigeon [2]	Year-round	Limited to None
Rock Wren	Breeding	Limited to None
Scaled Quail	Outside Normal Breeding Range [1]	Possibly Exists
Short-eared Owl	Outside Normal Breeding Range [3]	Limited to None
Spotted Towhee	Outside Normal Breeding Range [1]	Limited to None
Swainson's Thrush [M]	Outside Normal Breeding Range	-----
Vesper Sparrow	Outside Normal Breeding Range [1]	Possibly Exists
White-crowned Sparrow	Outside Normal Breeding Range	-----
White-faced Ibis [2]	Outside Normal Breeding Range [1]	Limited to None
Yellow-headed Blackbird [2]	Breeding	Limited to None
Yellow-rumped Warbler [2]	Outside Normal Breeding Range	-----

[M] = Migrant (according to Hanni 2005).

[1] = Within 100 mlles of breeding range edge.

[2] = Additional species detected during 2006 CNHP inventory.

[3] = Species is >100 mi from its breeding range edge based on BNA, but recent evidence suggests it is < 100 mi from its breeding range edge (R. Lock., RMBO, pers. comm.).

during the 2005 RMBO survey and inventory, the 2006 CNHP inventory, and/or the 2009-2012 RMBO point-count surveys. Of these 72 species, the Historic Site was determined to be within the normal breeding range (or peripheral breeding range in one case) of 50 species (69%) based on maps from the Birds of North America species accounts (Appendix J). Thirteen additional species were determined to be outside, but within 100 miles, of their normal breeding range. Given the potential for errors in the BNA range maps and/or the potential for us to have made errors in determining whether the Historic Site was within the normal breeding range from hard copy maps (GIS data were not available), we considered the additional 13 species when assessing whether breeding habitat exists for them at the park.

Species Comparisons using 2005 RMBO Bird Survey/Inventory List (Temporal Context)

Fifty-nine species of birds were observed at Sand Creek Massacre NHS in the 2005 RMBO surveys, and five additional species were observed in the 2006 CNHP inventory (Appendix I). Of these 64 bird species, 22

were not observed on recent (2009-2012) RMBO surveys (Table 4.11.4-1). However, six of these 22 species are outside of and more than 100 miles from their normal breeding ranges.

Of the remaining 16 species, eight are within their normal breeding range. However, none fall into the "existing" habitat class at the park; they fall into the "possibly exists" (three) or "limited to none" (five) categories. An additional eight species are outside of their breeding range but within 100 miles from the edge of their breeding range. Only two of these species fall into the "possibly exists" habitat class; the others fall into the "limited to none" category. From the comparison of species detected in 2005 and 2006 to 2009-2012, we do not have any particular concerns for species occurrence.

A different set of species (nine) was detected in the 2009-2012 surveys but not observed in the 2005 inventory (e.g., American Goldfinch, Baltimore Oriole, Blue Grosbeak, Common Yellowthroat; see Appendix I). Of these nine, one (Turkey Vulture), was observed during the 2006 CNHP rare species inventory.

Species Comparisons to Surrounding Region (Spatial Context)

During 2001-2005 RMBO surveys of birds in the surrounding region, 41 species were observed that have the potential to occur at Sand Creek Massacre NHS that were not detected during the 2009-2012 RMBO surveys (Table 4.11.4-2). This list of 41 species does not include species that were outside and greater than 100 miles from their normal breeding range. Also, there were an additional fifteen species on the regional list that were not detected in 2009-2012 that had been detected in either the 2005 RMBO survey/inventory or the 2006 CNHP rare species inventory at the Historic Site; these species were already accounted for and addressed in the temporal analysis.

Sixteen of the 41 species are within their normal breeding ranges, based on BNA species accounts, while the remaining 25 are outside, but less than 100 miles from their normal breeding ranges. Of the 16 species that are within their normal breeding ranges, the majority (12) are in the "limited to none" breeding habitat class. Four birds are in the "possibly exists" class, and none are in the "exists" class. The four species in the "possibly exists" class are the American Crow, Chihuahuan Raven, House Sparrow, and Long-billed Curlew. A review of the BBS data from nearby survey routes indicated that over the decade from 2000-2010, few American Crows, Chihuhuan Ravens, or Long-biled Curlews were counted on the four BBS routes. Relatively more House Sparrows were observed (60-130 individuals [all years combined] on three of the four routes).

Of the 25 species that are outside but within 100 miles of the edge of their breeding ranges, the vast majority (24) of species are in the "limited to none" breeding habitat class. Only one species is in the "possibly exists" class (Eastern Meadowlark); however, this species was not detected on any of the four BBS routes closest to the Historic Site. Given the status of their ranges and habitat preferences, we do not have any particular concerns with this list of 41 species.

Additionally, we compared the list of species detected at the Historic Site in 2009-2012 to the summary list from the four BBS routes for the period 2000-2010 (although not all routes were counted in all years). No additional bird species emerged as occurring in the region but not at Sand Creek Massacre NHS.

In summary, after comparison of species found in the surrounding region to those reported from recent RMBO surveys at Sand Creek Massacre NHS, a concern for bird species occurrence is not justified at this time.

Species of Conservation Concern

There are 14 species that have been detected at Sand Creek Massacre NHS during 2009-2012 RMBO surveys (in one or more of those years) that are listed as species of conservation concern on one or more of the lists described in Section 4.11.2 and Appendix H (Table 4.11.4-3). Additionally, there are five species that were detected in 2005 and/or 2006 surveys that are considered species

Table 4.11.4-2 Birds species detected in 2001-2005 regional surveys by RMBO throughout eastern Colorado that have the potential to be observed at Sand Creek Massacre NHS (Hanni 2005), but were not detected at the Historic Site during the 2009-2012 RMBO point-count surveys (41 species). This list excludes species (~20) that, at the Historic Site, are outside and greater than 100 miles from their normal breeding range.

Common Name	Rnage Status: Breeding or Outside Range but within 100 miles of Breeding	Breeding Habitat Class: Exists, Probably Exists, Limited to None
American Avocet	Breeding	Limited to None
American Coot	Breeding	Limited to None
American Crow	Breeding	Possibly Exists
Ash-throated Flycatcher	Outside Normal Breeding Range [1]	Limited to None
Bank Swallow	Breeding	Limited to None
Black-billed Magpie	Breeding	Limited to None
Black-necked Stilt	Outside Normal Breeding Range [1]	Limited to None
Black-throated Sparrow	Outside Normal Breeding Range	Limited to None (None)
Brewer's Sparrow	Outside Normal Breeding Range [1]	Limited to None
Cassin's Kingbird	Outside Normal Breeding Range [1]	Limited to None
Chestnut-collared Longspur	Outside Normal Breeding Range [1]	Limited to None
Chihuahuan Raven	Breeding	Possibly Exists
Common Raven	Outside Normal Breeding Range [1]	Limited to None
Cooper's Hawk	Breeding	Limited to None
Curve-billed Thrasher	Outside Normal Breeding Range [1]	Limited to None
Eastern Meadowlark	Outside Normal Breeding Range [1]	Possibly Exists
Ferruginous Hawk	Breeding	Limited to None
Gadwall	Outside Normal Breeding Range [1]	Limited to None
Golden Eagle	Outside Normal Breeding Range [1]	Limited to None
Gray Catbird	Breeding	Limited to None
Greater Roadrunner	Outside Normal Breeding Range [1]	Limited to None
Great-tailed Grackle	Breeding	Limited to None
Green Heron	Outside Normal Breeding Range [1]	Limited to None
House Sparrow	Breeding	Possibly Exists
Lazuli Bunting	Outside Normal Breeding Range [1]	Limited to None
Lewis's Woodpecker	Outside Normal Breeding Range [1]	Limited to None
Long-billed Curlew	Breeding	Possibly Exists
Mississippi Kite	Outside Normal Breeding Range [1]	Limited to None
Northern Bobwhite	Outside Normal Breeding Range [1]	Limited to None
Northern Pintail	Outside Normal Breeding Range [1]	Limited to None
Northern Rough-winged Swallow	Breeding	Limited to None
Purple Martin	Outside Normal Breeding Range [1]	Limited to None
Sage Thrasher	Outside Normal Breeding Range [1]	Limited to None
Scissor-tailed Flycatcher	Outside Normal Breeding Range [1]	Limited to None
Song Sparrow	Outside Normal Breeding Range [1]	Limited to None
Spotted Sandpiper	Breeding	Limited to None
Tree Swallow	Outside Normal Breeding Range [1]	Limited to None
Upland Sandpiper	Outside Normal Breeding Range [1]	Limited to None
Violet-green Swallow	Outside Normal Breeding Range [1]	Limited to None (None)
Virginia Rail	Breeding	Limited to None
Wilson's Snipe	Breeding	Limited to None
Yellow-breasted Chat	Outside Normal Breeding Range [1]	Limited to None

1 = Species is outside of its normal breeding range, but less than 100 miles from the edge of its breeding range.

Table 4.11.4-3. Summary of species detected during 2009-2012 RMBO surveys at Sand Creek NHS (or 2005 or 2006 surveys, *) of conservation concern, as listed by government agencies and non-governmental organizations.

Common Name	Listed Species		Species of Conservation Concern Lists								Comments
	Federal [1]	State [2]	US Fish & Wildlife Service			NAS/ ABC [3]	Partners in Flight				
							National Conservation Strategy [4]				
	USFWS	CPW (CDOW)	National	Region 6	BCR 18	2007 Watch List	BCR 18				
							CC	RC	CS	RS	
Brown Thrasher									●		
Burrowing Owl [5]		ST		●	●			●		●	[5] Species has not been observed since 2009 surveys (absence coincides with prairie dog population collapse).
Cassin's Sparrow								●	●	●	
Common Nighthawk								●			
Dickcissel									●		
Grasshopper Sparrow				●				●	●	●	
Horned Lark	PT [B]		B							●	[B] Listings with "B" are only for a subspecies that does not occur in CO, but PIF RS listing applies.
Lark Bunting					●	●		●	●	●	
Loggerhead Shrike *			●	●							*Species detected in 2005 or 2006 only.
Mountain Plover [5]		SC	●	●	●	●					[5] See comment above for Burrowing Owl.
Northern Harrier *								●			
Red-headed Woodpecker			●	●		●	●				
Ring-necked Pheasant [7]										●	[7] Because this is an introduced species, it will not be addressed further in this analysis.
Scaled Quail *						●		●	●		
Short-eared Owl *			●	●		●					
Swainson's Hawk			●			●				●	
Western Meadowlark								●		●	
Yellow-billed Cuckoo	C [D]	SC	D					●			[D] Listings with "D" are for a sub-population that does not occur east of the Rockies, but other listings (State and RC) apply.
Yellow-headed Blackbird *									●		

[1] Federal Listed Species Codes
T = Threatened C= Candidate
E = Endangered PT = Proposed Threatened

[2] State Listed Species Codes
ST = Threatened SE = Endangered
SC = Special Concern

[3] NAS/ABC - 2007 Watchlist
● = Red List
● = Declining or Rare

[4] PIF NCS Categories
CC = Continental Concern RC = Regional Concern
CS = Continental Stewardship RS = Regional Stewardship

of conservation concern, which we will also address in this section.

- USFWS / Listed Species: There are no bird species listed by the USFWS as endangered or threatened that are known to occur at Sand Creek Massacre NHS (USFWS 2012a). Although there is one species considered a candidate for listing (i.e., Yellow-billed Cuckoo) and one species proposed for listing as threatened (Horned Lark [Streaked Horned Lark]; USFWS 2012b), both listings apply only to birds in other parts of the western U.S. (see notes in Table 4.11.4-3).
- State of Colorado / Listed Species: There are no bird species that occur at the Historic Site that are listed as endangered by the state of Colorado; however, there is one species, the Burrowing Owl, that is listed as threatened (Colorado Parks and Wildlife 2012). Additionally, two species are listed as special concern by the state--Mountain Plover and Yellow-billed Cuckoo. These species are discussed in greater detail in the *Summary* section below.
- USFWS / Birds of Conservation Concern: There are eight species that have been detected at the Historic Site that have been identified by the USFWS as having the greatest conservation need at a National, USFWS Regional, or BCR geographic scale (U.S. Fish and Wildlife Service 2008). This includes two species that were not detected during recent RMBO surveys but during 2005 or 2006 surveys at the park.
- NAS / ABC: There are six species that occur or have occurred at Sand Creek Massacre NHS that have been listed on the NAS/ABC 2007 WatchList. One species, Mountain Plover, is listed on their Red List. The other five species are on the Yellow List, four because of population declines and one because it is rare.
- PIF: Fifteen of the 19 birds in Table 4.11.4-3 are listed by PIF in one or more of its categories (i.e., CC, RC, CS, RS). This includes two birds that were detected in 2005/2006 surveys but not in recent RMBO surveys at the park. Note that the Ring-necked Pheasant is on the PIF list, but because it is an introduced species, it will not be addressed further in this analysis.
- Colorado Species of Greatest Conservation Need: Six species that were detected at the Historic Site during the 2009-2012 RMBO surveys (and three that were detected during 2005-2006 surveys) are considered Tier 1 Species of Greatest Conservation Need in the State's Comprehensive Wildlife Conservation Strategy (CDOW 2006). All nine of these Tier 1 species already appear in Table 4.11.4-3 and are addressed, as appropriate, in the Summary section below. These Tier 1 species are: Burrowing Owl, Cassin's Sparrow, Lark Bunting, Loggerhead Shrike, Mountain Plover, Scaled Quail, Short-eared Owl, Swainson's Hawk, and Yellow-billed Cuckoo. Tier 2 species, which are relatively lower-priority Species of Greatest Conservation Need, are also listed in the Colorado plan.

Summary of Species Listed as Birds of Conservation Concern (Conservation Context)

For this summary, we emphasize species for which Sand Creek Massacre NHS has the greatest potential to positively impact their conservation during the breeding season, based on their habitat and range. We do not mean to imply that other seasons are not important for the conservation of birds, they are. Rather, we have limited this assessment to the breeding season because that is the only season for which we have current information. We also recognize that there is considerable uncertainty and subjectivity in our assessment. Thus, we do not mean to imply that the classes we assigned are the only "correct" categories. Rather, this represents our interpretation from the available evidence, but we fully expect that other interpretations might be appropriate.

Of the 18 species listed by one or more organization as being of conservation concern (Table 4.11.4-3, excluding the Ring-necked Pheasant), we believe that seven

Table 4.11.4-4. Species detected at Sand Creek Massacre NHS during 2009-2012 surveys that have also been identified as species of concern on one or more watch list. Species are organized by whether they have high, moderate, or low potential for the Historic Site to contribute to their conservation. Also shown is whether or not they were detected in either the 2005 RMBO survey/inventory or the 2006 CNHP rare species inventory.

Common Name	Detected During		Range Status	Breeding Habitat Class
	2005 or 2006 Survey/ Inventory	2009-2012 RMBO Surveys		
High Potential				
Burrowing Owl	•	• [1]	Breeding	Exists
Cassin's Sparrow	•	•	Breeding	Exists
Common Nighthawk	•	•	Breeding	Exists
Grasshopper Sparrow	•	•	Breeding	Exists
Horned Lark	•	•	Year-round	Exists
Swainson's Hawk	•	•	Breeding	Exists
Western Meadowlark	•	•	Year-round	Exists
Moderate Potential				
Dickcissel	•	•	Peripheral Breeding Range	Possibly Exists
Lark Bunting	•	•	Breeding	Possibly Exists
Loggerhead Shrike	•		Breeding	Possibly Exists
Mountain Plover	•	• [1]	Breeding	Possibly Exists
Northern Harrier	•		Year-round	Possibly Exists
Red-headed Woodpecker	•	•	Breeding	Possibly Exists
Low to No Potential				
Brown Thrasher	•	•	Breeding	Limited to None
Scaled Quail	•		Outside Normal Breeding Range [2]	Possibly Exists
Short-eared Owl	•		Outside Normal Breeding Range [3]	Limited to None
Yellow-billed Cuckoo		•	Outside Normal Breeding Range[2]	Possibly Exists
Yellow-headed Blackbird	•		Breeding	Limited to None

[1] Species observed in 2009 survey (2009 unpublished data collected by RMBO), but not since that time (absence coincides with prairie dog population collapse).

[2] Outside Normal Breeding Range, but within 100 miles of breeding range edge.

[3] Species is >100 mi from its breeding range edge based on BNA, but recent evidence suggests it is < 100 mi from its breeding range edge (R. Lock., RMBO, pers. comm.).

have sufficient habitat at the Historic Site to be considered as having high conservation potential (Table 4.11.4-4). These are the species that are within or on the edge of their normal breeding range and sufficient habitat exists at the Historic Site to support breeding. All of these seven species have been observed on recent (2009-2012) RMBO surveys. Furthermore, all but one (Burrowing Owl) of the species have been observed during all four years of surveys (Table 4.11.4-5). Some of the species, such as Cassin's Sparrow, Grasshopper Sparrow, Horned Lark, and Western Meadowlark, have been observed in relatively high numbers. Western Meadowlark was the nost abundant species at the Historic Site in 2011 and 2012, accounting for 27% and 31%, respectively, of the birds detected for the year; in the other two survey years, Western Meadowlark was the second or third

Table 4.11.4-5. The number of individuals of species with highest conservation potential detected at Sand Creek Massacre NHS during recent RMBO surveys.

Species	2009 Survey	2010 Survey	2011 Survey	2012 Survey	Total
Burrowing Owl	4	0	0	0	4
Cassin's Sparrow	187	175	193	189	744
Common Nighthawk	14	13	15	11	53
Grasshopper Sparrow	105	139	38	29	311
Horned Lark	113	116	92	53	374
Swainson's Hawk	1	1	4	4	10
Western Meadowlark	179	399	427	508	1,513

most abundant species. Cassin's Sparrow was among the top four most abundant species at the park in each of the four survey years.

The Burrowing Owl, a State-threatened species, was detected during recent RMBO surveys at the Historic Site in 2009 only. It was observed in the prairie dog colony at the upland grassland transect. Burrowing Owls were also observed during the 2005 RMBO survey/inventory and the 2006 CNHP rare species inventory. This species prefers low grass structure and burrows, such as those provided by prairie dogs (Hanni 2005). The Burrowing Owl was one of the targeted species in the CNHP rare species inventory at the Historic Site, and Sovell et al. (2008) reported observing 18 Burrowing Owls. As discussed in the Prairie Dog chapter of this NRCA, the sylvatic plague decimated the prairie dog colonies at the Historic Site and on surrounding lands in early 2010. As of early 2013, the status of prairie dogs at the park remains unchanged. Although Burrowing Owls have not been observed since prairie dogs have been absent from the Historic Site, it is possible that the owl species may be detected in the future.

Based on our assessment, we consider the Mountain Plover (a State special concern species) to have moderate potential for the Historic Site to contribute to its conservation. We mention this species here because of its conservation status (see Table 4.11.4-3), and because its occurrence also may have been affected by the loss of prairie dogs at and adjacent to the park. Like the Burrowing Owl, the Mountain Plover was detected during recent RMBO surveys only in 2009 (2 individuals). It too was detected in the prairie dog colony at the upland grassland transect. The species was also observed during the 2005 RMBO survey/inventory and the 2006 CNHP rare species inventory. Like the Burrowing Owl, the Mountain Plover prefers low grass structure (Hanni 2005). During the 2006 CNHP inventory, plovers were observed immediately outside of the Historic Site boundary near the north prairie dog colony (Sovell et al. 2008). In addition to the Mountain Plover, five other species (of the 18 total) are considered to have moderate potential for the Historic Site to contribute to their conservation.

In summary, all species of conservation concern that are within their normal breeding range and have "existing" breeding habitat at the Historic Site have been observed during recent (2009-2012) RMBO surveys. Based on this, we consider the condition for species of conservation concern to be good; however, we do have some concern for the Burrowing Owl, and to a lesser degree the Mountain Plover, which have not been observed since Black-tailed prairie dogs have disappeared from the park.

Overall Condition

For assessing the condition of landbirds, we used one indicator/measure that assessed landbird occurrence. This indicator is summarized in Table 4.11.4-6. Although our assessment is based on limited data, with the exception of the Burrowing Owl, we found no justification to warrant concern for landbird

Table 4.11.4-6. Summary of the landbirds indicators/measures and their contributions to the overall landbirds natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator / Measure to the Overall Resource Condition.
Species Occurrence • Temporal context • Spatial context • Conservation context	Although other measures that are currently not available (i.e., data for density, occupancy, etc.) may be more appropriate for this measure, we simply used occurrence for this assessment. We considered three different facets of occurrence to provide a greater perspective to this measure.	A total of 72 bird species have been reported to occur at the Historic Site, with 50 of those species occurring within and 13 species occurring <100 miles from their primary breeding range. Forty-one species of birds were identified that occur in the region but have not been recently observed at the Historic Site during RMBO breeding bird surveys (16 within their normal breeding range, and 25 <100 miles from their breeding range edge). The Historic Site has a high potential to influence 7 species that have been identified as species of concern by various bird conservation organizations.

occurrence at Sand Creek Massacre NHS at this time.

From the comparison of species detected in 2005 and 2006 to 2009-2012, we do not have any particular concerns for species occurrence. The temporal comparison found 22 species that were not detected during recent RMBO surveys. However, six of these 22 species are outside of and more than 100 miles from their normal breeding range. Eight of the 22 species are within their normal breeding range, but none fall into the "existing" habitat class at the park; they fall into the "possibly exists" (three) or "limited to none" (five) categories. An additional eight species are outside of their breeding range but within 100 miles from the edge of their breeding range; however, only two of these species fall into the "possibly exists" habitat class (the others fall into the "limited to none" category).

Similarly, there was nothing particularly surprising or alarming when comparing species observed during recent RMBO surveys to the species observed during 2001-2005 regional RMBO surveys (i.e., list presented by Hanni 2005). Forty-one species were observed that have the potential to occur at the Historic Site that were not detected during the 2009-2012 RMBO surveys. Although 16 of these species are within their normal breeding ranges, the majority (12) have little to no breeding habitat at the park. Only four species may have breeding habitat available, but for three of the four species few individuals were counted on BBS routes in the vicinity of the park. Of the 25 species that are outside but within 100 miles of the edge of their breeding ranges, nearly all have little to no breeding habitat at the park.

We found seven species that we believe have relatively high conservation potential at Sand Creek Massacre NHS, and most of these have been observed numerous times at the Historic Site during recent years. The main exception to this is the Burrowing Owl, a State-threatened species, which has not been observed at the Historic Site starting in 2010. Black-tailed prairie dogs, which provide nesting habitat for Burrowing Owls and other species, disappeared from the park in 2010 due to an outbreak of the sylvatic plague.

With the exception of concern for the Burrowing Owl (and to a lesser extent the Mountain Plover), based on the evidence presented here, we consider the condition of birds at the Historic Site to be good. Unfortunately, we do not have sufficient data to justify a trend in that condition, although ongoing monitoring should provide such an estimate for future assessments.

Level of Confidence/Key Uncertainties

The key uncertainties related to this assessment are the overall lack of data and subjectivity with respect to assigning individual species to range, habitat, or conservation classes. Although we are currently collecting data that will provide for a quantitatively rigorous analysis in the future, at the present time we relied primarily on qualitative indicators to assess the condition of landbirds.

We determined the breeding ranges primarily from the BNA species accounts and had to judge from online and hard copies whether or not the Historic Site was within those ranges. We tried to account for this uncertainty by also including species that were on the edge of their ranges (i.e., less than 100 miles from the breeding range edge). Similarly, there is considerable subjectivity in our assignment of habitat classes. We based this assessment on a combination of the BNA accounts, as well as our own and local knowledge of the species in question.

Although the RMBO regional data used for the spatial comparison were from an earlier period (2001-2005) than the current occurrence data (2009-2012), we supported our analysis by using data from the BBS covering 2000-2010. We found this approach successful, in that no additional bird species emerged as "missing" from the Historic Site.

4.11.5. Sources of Expertise

Ross Lock, a wildlife biologist with RMBO, provided consultation and reviewed the landbirds chapter.

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4.12. Black-tailed Prairie Dog (*Cynomys ludovicianus*)

Indicators/Measures

- Area occupied and Density of prairie dogs

Condition – Trend - Confidence



Significant Concern – Unchanging - High

4.12.1. Background and Importance

Prairie dogs, which occur only in North America, are burrowing rodents that belong to the squirrel family. Prairie dogs are diurnal and live in colonies, or towns, which sometimes contain thousands of individuals and extend for miles. There are five species of prairie dogs, all of which may be considered rare (Hoogland 2006a). The black-tailed prairie dog (*Cynomys ludovicianus*) (Figure 4.12.1-1), the most abundant, widespread, and conspicuous of the five species, occurred at Sand Creek Massacre NHS until the spring of 2010. In 2010, the prairie dog colonies on the Historic Site were decimated by sylvatic plague. As of late 2012, the colonies have not yet returned. However, because of the significant ecological role that prairie dogs play in the landscape (described below), including at the Historic Site, their status as a management issue for the park, and because prairie dogs may, on their own, eventually return to their once-inhabited towns at Sand Creek Massacre NHS, they are included in this NRCA.

Prairie dogs are an important component of the ecosystems they inhabit. They directly and indirectly influence grasslands through their grazing and burrowing and as prey (Kotliar et al. 2006). Through their foraging and clipping of vegetation to maintain their habitat, as well as the mixing of subsoil and topsoil during excavations, prairie dogs affect the redistribution of minerals and nutrients, encourage penetration and retention of moisture, and affect plant species composition (Kotliar et al. 2006). Although they reduce the biomass of vegetation, they often also enhance the digestibility, protein content, and productivity of grasses and forbs at colony-sites (especially young colony-sites) that are preferred by large herbivores. Prairie dog colony-sites may extend for miles and



PHOTO: RON SINGER

Figure 4.12.1-1 Black-tailed Prairie Dog (*Cynomys ludovicianus*), named for its characteristic, black-tipped tail.

contain hundreds of mounds that surround their burrow entrances. Black-tailed prairie dog mounds may be as high as 2.5 feet (0.75 meters), with a diameter up to 7 feet (2 meters; Hoogland 2006b). Because black-tailed prairie dogs eat or clip grasses and other plants that grow taller than about 12 inches (30 centimeters), vegetation at colony-sites is relatively short (Hoogland 2006b). Prairie dog burrows and colony-sites provide shelter and nesting habitat for a variety of animals (only some of which occur at Sand Creek Massacre NHS), including insect and arachnid species, burrowing owls (*Athene cunicularia*), mountain plovers (*Charadrius montanus*), horned larks (*Eremophila alpestris*), and black-footed ferrets (*Mustela nigripes*) (Figure 4.12.1-2). Among the animals that consume prairie dogs are black-footed ferrets (which do not occur at the Historic Site), American badgers (*Taxidea taxus*), long-tailed weasels (*Mustela frenata*), bobcats (*Felis rufus*), coyotes (*Canis latrans*), ferruginous hawks (*Buteo regalis*), golden eagles (*Aquila chrysaetoes*), prairie falcons (*Falco mexicanus*), bull snakes (*Pituophis melanoleucus*), and prairie rattlesnakes (*Crotalus viridis*). Additional species use prairie dog towns (see Sovell et al. 2008).

Within colonies, prairie dogs live in family groups called coteries. The size of a coterie ranges from 1 to 26 individuals, but a coterie generally consists of 1 breeding male, 2-3 adult females, and 1-2 yearling offspring of each gender (Hoogland 2006a). Most black-tailed prairie dogs reach sexual maturity and mate in the second February-March following their birth. Female prairie dogs have one litter of young per year, with the most common litter size being three. Breeding takes place in late January through early March, and gestation length is typically 34-35 days. On average, young emerge from the natal burrow 41 days after birth.

Black-tailed prairie dogs are thought to have once occupied 74 million acres from Canada to Mexico (Proctor et al. 2006), including parts of eleven states (Hoogland 2006b). Estimates for the species' occurrence in Colorado ranged from 3 million to 7 million acres (Clark 1989, Knowles 1998, as cited in Sovell 2008). However, after 200 years of shootings, poisonings, conversion of habitat, and more recently sylvatic plague, prairie dog numbers are a fraction of what they once were (Hoogland 2006b). Sylvatic plague, caused by the bacterium Yersinia pestis, is a disease transmitted by fleas; it can be contracted by various mammals and may kill nearly all


PHOTO: ROB BENNETTS


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PHOTO: BRYAN HARRY


PHOTO: VICTORIA DRIETZ

Figure 4.12.1-2 Species that benefit from black-tailed prairie dogs,clockwise from top left: Burrowing Owls (*Athene cunicularia*); Horned Lark (*Eremophila alpestris*); Mountain Plover (*Charadrius montanus*); and American badger (*Taxidea taxus*).

prairie dogs in an infected colony (USGS 2008). Today, the black-tailed prairie dog's overall range is similar to its historic range, but it occupies only about 1.2 to 2.1 million acres (Proctor et al. 2006). An estimate for 2003 for Colorado was 631,578 acres occupied (Luce et al. 2006). In 2004, it was estimated that black-tailed prairie dogs inhabited about 6,900 acres of land managed by the NPS in the western United States (not including the Sand Creek Massacre NHS; Sidle et al. 2006).

Black-tailed prairie dogs moved onto the land that would become part of the Sand Creek Massacre NHS starting in 2001 (Sovell 2008). They eventually established two colonies in shortgrass prairie habitat (dominated by *Bouteloua gracilis* and *Buchloe dactyloides*), one in the northwest part of the Historic Site and one in the southeast part of the park. In 2006, they occupied a total of 228 acres (92.3 hectares) (Sovell et al. 2008) (Figure 4.12.1-3). Species associated with prairie dogs were also reported at that time — burrowing owls on the prairie dog complex and mountain plovers within the complex but just outside of the Historic Site boundary. Prairie dog predators (or their sign) were also reported — badgers, coyotes, and ferruginous hawks (just outside the Historic Site) (Sovell et al. 2008).

Management of the black-tailed prairie dog varies substantially across its range; some states consider it a species of special concern, other states consider it a small game species, and still others consider it a vertebrate pest (USGS 2009). Because prairie dogs are both an important component of the ecosystem and, in some cases, damaging to other resources within and adjacent to park units, their management is important and complex. The policy of the National Park Service is to conserve and recover the black-tailed prairie dog wherever possible (Sovell 2008). The NPS can control prairie dogs on its property only to protect human health and safety, for good neighbor relations, and to manage conflicts with other Historic Site objectives, such as the preservation of cultural resources.

Sand Creek Massacre NHS developed a Prairie Dog Management Plan and Environmental Assessment in 2008 "to manage for long-term, self-sustaining prairie dog populations at the Historic Site while avoiding negative impacts to landowners that do not wish to accommodate prairie dogs on their properties. An associated effect of the Plan is the increased long-term viability of species closely dependent on the prairie dog ecosystem" (Sovell 2008). The management plan discusses potential management options for controlling prairie dogs, including: use of vegetative barriers and/or grazing management to discourage colony expansion; conservation easements; use of fencing and other visual barriers to prevent colony expansion; live trapping and translocation of prairie dogs; and the use of approved rodenticides to control populations (Sovell 2008). The plan includes monitoring for both prairie dogs and vegetation.

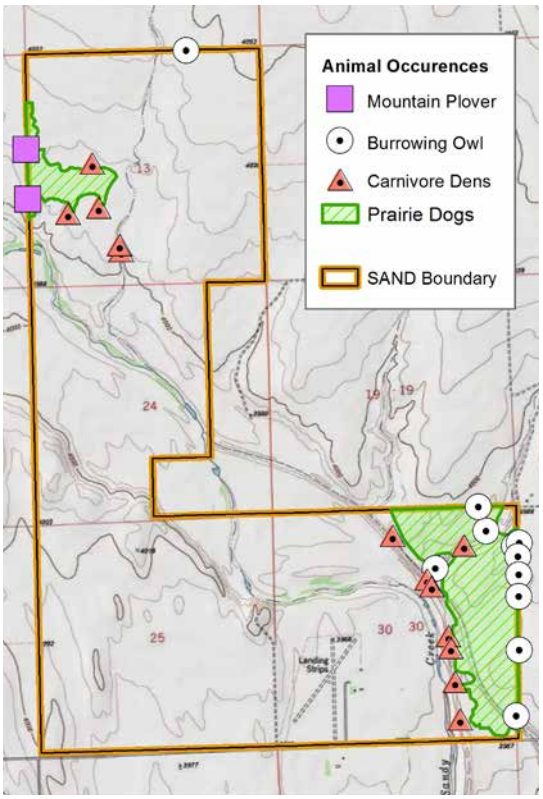


Figure 4.12.1-3. Prairie dog colonies in 2006, and the occurrence of other species of concern. Adapted from Sovell et al. (2008).

4.12.2. Data and Methods

Because the Historic Site is relatively recently established and the prairie dog colonies within the boundaries were relatively young, there is not an extensive history of prairie dogs at the Historic Site. This assessment is based on the information that is available. These primary information sources are described immediately below and consist of: 1) a 2006 rare vertebrate species inventory at

the Historic Site conducted by the Colorado Natural Heritage Program (CNHP; Sovell et al. 2008); 2) the Historic Site's prairie dog management plan and environmental assessment (Sovell 2008); and 3) a study on the prairie dog populations at Sand Creek Massacre NHS (and three other small NPS units) (Pigg and Cully 2010, and Goldberg 2012). This description of primary information sources is followed by a discussion of the indicators/measures we used to determine the condition of prairie dogs at Sand Creek Massacre NHS.

Primary Data Sources

2006 Rare Vertebrate Species Inventory by CNHP (Sovell et al. 2008)

A rare vertebrate species inventory was conducted at Sand Creek Massacre NHS in 2006, and the inventory included sampling for prairie dogs (Sovell et al. 2008). The objective for prairie dogs was to determine the extent of the colonies (i.e., the area inhabited) and estimate density (i.e., number of prairie dogs per hectare) using methods described in Plumb et al. (2001), a protocol developed for seven national parks. The sampling was conducted from June 14-18, 2006. The sampling method used a 200 m x 200 m (4-hectare) plot in each prairie dog colony to conduct visual counts. Prairie dogs were counted 24 hours after plots were established in their habitat.

Another component of the inventory was to estimate the densities of mountain plover, ferruginous hawk, and burrowing owl populations.

Prairie Dog Management Plan and Environmental Assessment (Sovell 2008)

Using aerial photography, Sovell (2008) provided a history of the two black-tailed prairie dog colonies at the Historic Site (and on surrounding land). The author also discussed estimated future trends in the prairie dog colonies at Sand Creek Massacre NHS, and a suggested density for the colonies to prevent degradation of the habitat.

Study of Prairie Dogs at Sand Creek Massacre NHS (Pig and Cully 2010, and Goldberg 2012)

Because additional information was needed on the prairie dog populations at Sand Creek Massacre NHS (and other parks), such as on their dispersal to adjacent lands, a project (Status and Management of Black-tailed Prairie Dogs on Small Cultural National Parks of the Western Great Plains) was devised to collect information over multiple years. At Sand Creek Massacre NHS, the study was to provide baseline demographic and dispersal data and an increased understanding of the role of the prairie dog's contribution to native ecosystem diversity. Unfortunately, the 2010 sylvatic plague event at the Historic Site interrupted the study. Pigg and Cully (2010) contains results for one year (2009) of the study; density estimates and some information from radio telemetry work are provided. They used two methods to estimate prairie dog density. One method used the protocol of Plumb et al. (2001; the same as used in Sovell et al. 2008), and the other used capture data and models in program CAPTURE. We mention both density estimates, but use those from the 4-hectare visual count plots so the numbers are comparable to the estimates from Sovell et al. (2008).

Although the study ended at Sand Creek Massacre NHS in early 2010 due to the sylvatic plague, the study continued at other NPS units, and relevant information was collected on prairie dog dispersal and estimating abundance (Goldberg 2012).

Indicators/Measures

Area occupied and Density of prairie dogs

Estimates of prairie dog populations are usually based on the amount of occupied habitat, rather than on the number of individual animals (USFWS 2009). However, densities of prairie dogs (the number of animals per unit of area) may also be estimated. Because we have some, but limited, information on each of these metrics, we present both.

We assessed area occupied/density of prairie dogs by looking at changes in the area occupied/density of prairie dogs over time.

These assessments were conducted using the primary data sources described above.

We also report on the documented occurrence of species that ecologically benefit from prairie dogs at the Historic Site, both before and after the colonies' disappearance.

4.12.3. Reference Conditions

Reference conditions for prairie dogs are complex and highly dependent on the perspective from which they are taken. For example, a landowner that makes his or her living from production needs to consider the decreased plant biomass associated with prairie dog colonies, as well as the potential for injury of stock animals. Thus, from their perspective the condition of the resource may be best when prairie dogs are in very low numbers or entirely absent. In contrast, from an ecological perspective, prairie dogs have a pronounced impact on their ecosystem (Kotliar et al. 2006). As discussed in Section 4.12.1, prairie dogs increase habitat diversity and contribute to grassland ecosystem processes. Prairie dogs clip the vegetation and maintain open habitats preferred by some animals, such as the horned lark and mountain plover. Many species, such as the American badger, prairie rattlesnake, burrowing owl, and the federally endangered black-footed ferret, prey on prairie dogs or use their burrows for shelter. Thus, from an ecological standpoint, having a healthy population of prairie dogs may be viewed positively, especially when considering the suite of other species that may benefit from their presence. However, even from an ecological perspective, having an overabundance of prairie dogs may have detrimental consequences to the vegetation.

In this NRCA, we focus on the prairie dog's ecological role in the grassland ecosystem. We do, however, acknowledge that prairie dogs in a national park unit also pose difficulties to management, particularly with regard to adjacent land owners who do not value prairie dogs on their property, and the damage that prairie dog excavations can cause to important cultural resources that the park must protect. The draft Sand Creek Massacre NHS Prairie Dog Management Plan and Environmental Assessment identifies an appropriate density of 10 prairie dogs per acre (Sovell 2008). This is about half of that reported by Hoogland (2006a) as being typical, but the Hoogland (2006a) density does not necessarily represent a desired condition for Sand Creek NHS after taking into account the various considerations (Sovell 2008).

4.12.4. Condition and Trend

Area occupied and Density of prairie dogs

The history of the two prairie dog colonies at Sand Creek Massacre NHS (and on surrounding land) was described by Sovell (2008). Prairie dogs have been present in the area to the northwest of the Historic Site since 1980, and it was estimated that they occupied about 65 acres (26 hectares) of shortgrass prairie in this area in 1989 (Sovell 2008). Nearly ten years later, in 1998, they had expanded in acreage and occupied an estimated 525 acres (213 hectares). The prairie dog colony continued to expand, and by 2006 it covered an estimated 1,453 acres (588 hectares), for the first time (as far as known) including an area in the northwest portion of the Historic Site (see Figure 4.12.4-1). Based on aerial photography, no prairie dog colony was present in the southeast area of the Historic Site in 1989 or 1998. Only a few years later, however, in 2001, prairie dogs occupied an estimated 60 acres (24 hectares) within what is now the boundary of the Historic Site (Sovell 2008). Based on his examination of aerial photography, Sovell (2008) reported that there was no evidence that this southeast colony extended onto the land adjacent to the Historic Site in 2001. By 2006, however, the southeast colony had expanded to 510 acres (206 hectares) total, including onto land adjacent to the Historic Site (see Figure 4.12.4-1).

The discussion below focuses on the portion of the colonies within the Historic Site boundaries.

North Colony

There are no estimates for the acreage occupied by prairie dogs within the boundaries/ eventual boundaries of the northern portion of the Historic Site prior to 2006. Prairie dogs expanded into this area sometime between

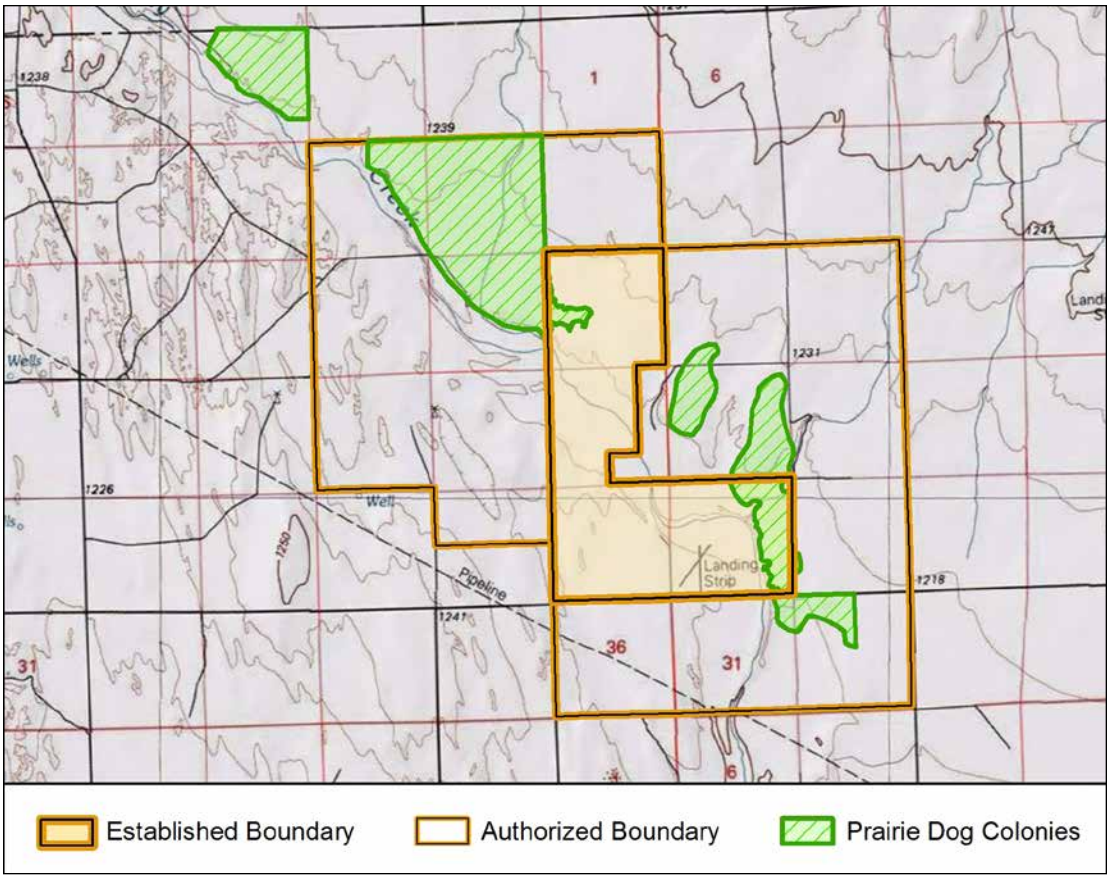


Figure 4.12.4-1 Prairie dog colonies within and outside of Sand Creek Massacre NHS boundaries in 2006. Figure adapted from Sovell (2008).

Table 4.12.4-1. Area occupied and estimated densities of black-tailed prairie dogs at Sand Creek Massacre NHS.

Colony	Year	Area Occupied in Acres (and Hectares)	Density of prairie dogs in Acres (and Hectares)	Source
North	2006	41.02 acres (16.6 ha)	13.3/acre (33/ha)	Sovell et al. (2008)
North	2009	9.88 acres (4 ha)	No Data	GIS map from the Historic Site
North	2010-2012	0 acres (0 ha)	0	K. Zimmerman, NHS, pers. com.
South	2001	60 acres (24.3 ha)	No Data	Sovell (2008)
South	2006	187.05 acres (75.7 ha)	19.8/acre (49/ha)	Sovell et al. (2008)
South	2009	153.20 acres (62 ha)	No Data	GIS map from the Historic Site
South	2009	No Data	17.8/acre (44/ha)	Pigg and Cully (2010)
South	2010-2012	0 acres (0 ha)	0	K. Zimmerman, NHS, pers. com.

1998 and 2006 (Sovell 2008). In June 2006, the CNHP estimated that prairie dogs occupied 41.0 acres (16.6 hectares) of shortgrass prairie in this area (Table 4.12.4-1; Figure 4.12.1-3) (Sovell et al. 2008).

The estimated area occupied in 2009 had dropped to 9.9 acres (4 hectares) (Table 4.12.4-1; Figure 4.12.4-2). Starting in the spring of 2010 to the present time (late 2012; i.e., 2010, 2011, 2012), the acreage occupied by prairie dogs in the north colony of Sand Creek Massacre NHS was/is 0 acres (Karl Zimmermann, Sand Creek Massacre NHS, pers. comm.).

South Colony

There are four estimates of the acreage occupied by prairie dogs in the south colony from 2001 to 2010. The area occupied by

prairie dogs increased from 60 acres (24.3 ha) in 2001 (Sovell 2008) to 187.1 acres (75.7 ha) in 2006 (Sovell et al. 2008), and then dropped to 153.2 acres (62 ha) in 2009 (Table 4.12.4-1; Figures 4.12.1-3 and 4.12.4-2). As with the north colony, the south colony experienced 100% mortality in 2010 (Karl Zimmermann, Sand Creek Massacre NHS, pers. comm.; Goldberg 2012), and prairie dogs have not been observed in the south colony since.

Sovell (2008) provided evidence that the prairie dog colonies at the Historic Site were expanding at the time (2006 to early 2008) and would probably continue to do so in the immediate future. He noted that both of the colonies were young and surrounded by suitable shortgrass prairie habitat for expansion. Additionally, prairie dog colonies tend to expand at higher rates during periods of below average rainfall or drought (Augustine et al. 2007; Sovell 2008), and such conditions were predominant in the Historic Site vicinity from 2000-2007 (Sovell 2008).

Prairie Dog Densities

In June 2006, the CNHP estimated that the prairie dog density in the north colony within the Historic Site was 13.3 prairie dogs/acre (33/hectare), and that in the south colony within the Historic Site was 19.8 prairie dogs/acre (49/hectare) (Sovell et al. 2008; Table 4.12.4-1). Pigg and Cully (2010) estimated density during two periods in 2009- June 19-25th and August 2-6th. We present only the estimate from June, as this was the same time-frame as the 2006 estimates of the CNHP. Pigg and Cully (2010) did not indicate which colony they sampled; however, Historic Site staff indicated that the south colony was sampled. The density estimate in June was 17.8 prairie dogs/acre (44/hectare). The density estimates from the CAPTURE analysis were similar to the densities from the visual counts (i.e., 44/ha from visual counts compared to 41.8/ha from CAPTURE; Pigg and Cully 2010).

As previously described, the Pigg and Cully (2010) work was to continue for multiple years, but the project was interrupted due to the sylvatic plague. Densities at both colonies dropped to 0 prairie dogs in spring 2010 due to plague (Karl Zimmermann, Sand Creek Massacre NHS, pers. comm.; Goldberg 2012). As described above, no prairie dogs have been observed since.

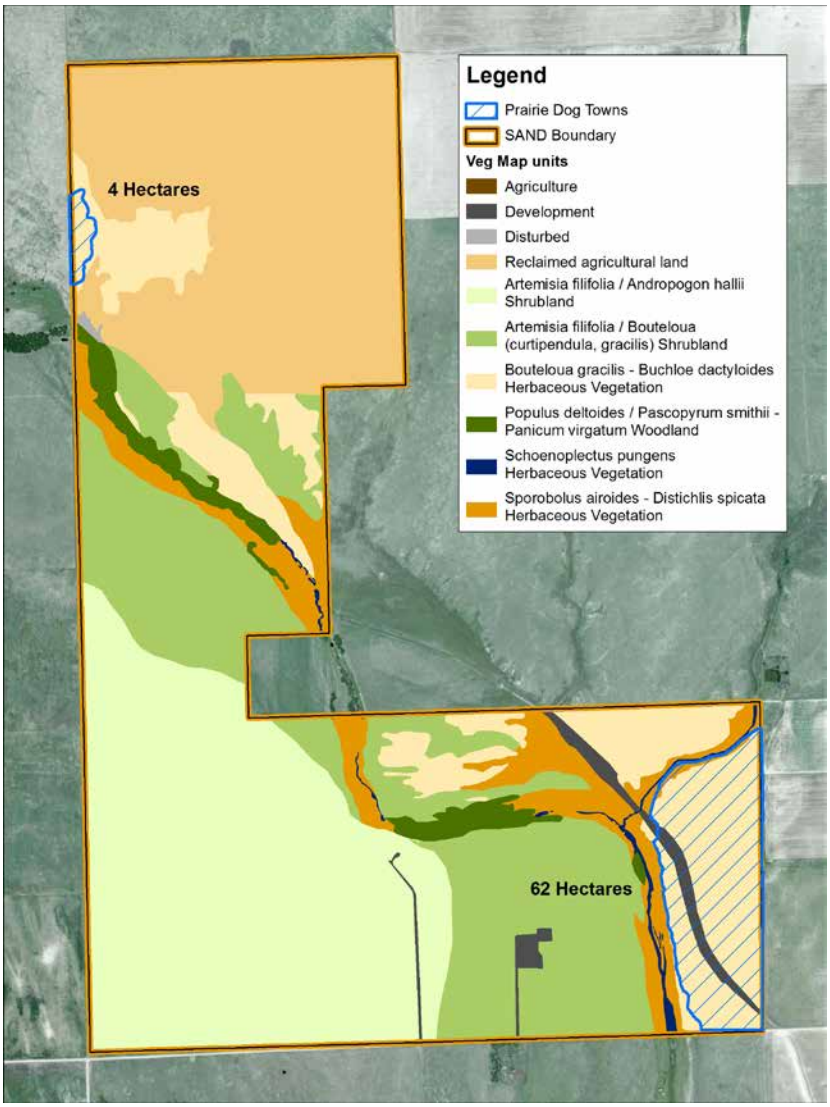


Figure 4.12.4-2. Prairie dog colonies in 2009. Source: Sand Creek Massacre NHS.

Several studies have provided precise determinations of prairie dog colony densities at various locations (Hoogland 2006a), and these densities ranged from 3 to 27 individuals per acre (8 to 68 per hectare). Prairie dog densities vary over time and space due to factors such as forage, climate, predation, and disease. Given that such variations occur, a crude estimate of colony density before juveniles first emerge from their natal burrows is 10 adults and yearlings per acre (25 adults and yearlings per hectare) (Hoogland 2006a). A crude estimate for after

juveniles first emerge (in May and June) is 20 adults, yearlings, and juveniles per acre (or 50 per hectare). The 2006 and 2009 estimates for the colonies at Sand Creek Massacre NHS were obtained in June, so the estimated densities were comparable to those reported by Hoogland (2006a) for this time-frame.

Detection of species associated with Prairie Dog Colonies

Here we also report on the documented occurrence of species at Sand Creek Massacre NHS that ecologically benefit from prairie dogs. Based on available information, we examine species occurrence before and after the plague event.

The first inventory of the Historic Site, that conducted by CNHP in 2006 (Sovell et al. 2008), documented burrowing owls (18 counted) on the southern prairie dog colony, and mountain plovers (4 counted) immediately adjacent to the Historic Site in the northern prairie dog colony (Figure 4.12.1-3). While ferruginous hawks were not observed on the Historic Site at this time, they were on adjacent lands, and they have been reported on the Historic Site property in the past. During the inventory, researchers also observed signs of American badger and coyote (see Figure 4.12.1-3).

There are two other sources of information on the occurrence of the bird species before and after the prairie dog colonies' disappearance. The first is based on conversations with Historic Site staff (i.e., Karl Zimmermann), and the second is landbird monitoring data collected annually during the avian breeding season by the Rocky Mountain Bird Observatory (RMBO; described in detail in the Landbirds Chapter). Although not based on sampling, Historic Site staff reported that after the disappearance of the prairie dog colonies, burrowing owls and mountain plovers have not been observed; this is in comparison to observing a few burrowing owls per day prior to the 2010 plague. This observation is supported by RMBO data and reports. According to Lock et al. (2012a), RMBO monitoring data from 2009-2011 indicated that burrowing owls and mountain plovers were detected in the southern prairie dog colony in 2009, but not in 2010 or 2011 when prairie dogs were no longer present. These species were also not observed during RMBO sampling in 2012 (Lock et al. 2012b).

Overall Condition and Trend

Based on the information available at this time, and using the ecological reference condition stated in Section 4.12.3, the condition of the black-tailed prairie dog at Sand Creek Massacre NHS is of significant concern. This indicator is summarized in Table 4.12.4-2. The trend is unchanging at this time; the condition had deteriorated in 2010, when the population was reduced to zero. The population could not deteriorate from that point, and there is no evidence of an increase at this time. As discussed in the next section, however, the prairie dog population at the Historic Site could increase in the future (although this is an area of high uncertainty).

The two prairie dog colonies at the Historic Site were decimated by sylvatic plague in early 2010. Apparently, 100% mortality of prairie dogs occurred, and prairie dogs have not yet returned to the Historic Site more than two years later. Prior to the 2010 plague event, plague had not been recorded in the immediate vicinity of Sand Creek Massacre NHS (Sovell 2008); however, prairie dog populations in the surrounding area of Sheridan Lake and Swede Lake had experienced plague in the past (Sovell 2008). Monitoring of the once-inhabited prairie dog colonies has continued since 2010, whereby Historic Site staff visually scan the colonies using binoculars (K. Zimmermann, Sand Creek Massacre NHS, pers. comm.). Once per year, a more thorough assessment of the colonies is made.

At least in the short term, there is some evidence that the loss of prairie dogs at the Historic Site has influenced the occurrence of at least two bird species, the burrowing owl and the mountain plover. As described earlier, both species are known to benefit from prairie dog colonies in the form of shelter and nesting habitat. Although based on only a few years of monitoring data, neither of these species have been detected during annual RMBO landbird surveys since 2009 (i.e., 2010-2012).

Table 4.12.4-2. Summary of the prairie dog indicators/measures and their contributions to the overall black-tailed prairie dog natural resource condition assessment.

Indicator/Measure	Description of How the Indicator(s) Contributes to the Overall Resource Condition	General Contribution of this Indicator or Measure to the Overall Resource Condition.
Area occupied and Density of prairie dogs	Both area occupied and density of animals are used to assess prairie dog populations, although area occupied has been used more frequently. We used both measures because we had limited data on each.	The assessment was based on area occupied and density of prairie dogs by looking at changes in the area occupied/density of prairie dogs over time. Acreages occupied and prairie dog densities were estimated for both prairie dog colonies in some years from 2001-2009. The north colony occupied 9.88 acres in 2009, but occupied 0 acres in 2010. The south colony occupied 153.20 acres in 2009, but occupied 0 acres in 2010. The density of prairie dogs in the north colony decreased from 13.3 prairie dogs per acre (measured in 2006) to 0 in 2010. The density in the south colony decreased from 17.8 prairie dogs per acre in 2009 to 0 in 2010. In early 2010, the sylvatic plague decimated the colonies at the Historic Site, resulting in 100% mortality (based on available information). No prairie dogs have been observed at the Historic Site since that time.

No data are available to assess effects on other bird and mammal species that are known to benefit ecologically from prairie dogs.

Although prairie dogs provide numerous ecological benefits, they are also known for causing damage to resources on national park units (e.g., cultural or archaeological sites) and concern to adjacent landowners who do not want prairie dogs on their land. As described previously, the Historic Site had developed a prairie dog management plan for the Historic Site to minimize such potential problems with prairie dogs. Additionally, prairie dogs have the potential to greatly transform vegetation landscapes (Beals 2012, Seastedt et al. 2013), and their absence assists managers in maintaining the native status of the grasslands. At least for the time being, prairie dog management efforts at Sand Creek Massacre NHS are not needed.

Level of Confidence/Key Uncertainties

According to the best available information, the prairie dogs within and outside of the Sand Creek Massacre NHS suffered 100% mortality by early 2010 (Karl Zimmermann, Sand Creek Massacre NHS, pers. comm.). As far as is known, no prairie dogs survived in at least a 5 mile radius of the Historic Site. There is a possibility, however, that prairie dogs could recolonize, on their own, areas outside or within the Historic Site in the future. This is an area of uncertainty.

Factors influencing recolonization would include whether 100% mortality of prairie dogs outside of the Historic Site actually occurred; the distance from the Historic Site to the closest active prairie dog town(s), and the habitat in between (i.e., would the land between be conducive to prairie dog movements); and dispersal distances of prairie dogs. Although these questions cannot be answered at this time, there are some data available.

Some information on black-tailed prairie dog recolonization rates is available from studies involving control of prairie dog populations. For instance, Knowles (1986) found that it took 3-5 years for colonies receiving a 95% population reduction (using zinc phosphide) to obtain pretreatment numbers. Similarly, Crosby and Graham (1986) estimated that a black-tailed prairie dog population reduced by 77% or less would likely attain pre-control levels within 3 years (so a population reduced by more than 77% would take longer than 3 years to recover). A study of a prairie dog colony whose abundance was reduced by 95% due to plague (and the colony area was

reduced by 89%) found that more than half of the surviving individuals had antibodies to *Yersinia pestis* (Pauli et al. 2006). The authors pointed out that although others have suggested that colony growth after a plague event is probably due to recolonization by prairie dogs dispersing from other colonies (Antolin et al. 2002), plague survivors may be critical in repopulating the colony.

Two other recent studies provide some information on dispersal rates and distances of prairie dogs. One study, using nearly 150 VHF collars and a handful of GPS collars, observed eight intercolony dispersal events over the three-year study (Goldberg 2012). Yearling males, adult females, and yearling females were the most likely to disperse from the colony. Three kilometers (1.9 miles) was the longest confirmed dispersal distance, although a few dispersals of up to 6.5 kilometers (4 miles) may have occurred. Another study found that related individuals were found up to 60 kilometers (37.3 miles) distant from one another, although it may have taken more than one generation to disperse the distance (Wisely et al. 2012).

4.12.5. Sources of Expertise

For this assessment, we relied on previous reports and publications and personal communications with NHS personnel.

4.12.6. Literature Cited

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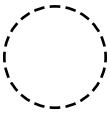
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4.13. Rare Vertebrates

Indicators/Measures

- Presence/absence of vertebrate species

Condition - Trend - Confidence



Insufficient Data - Insufficient Data - Low

4.13.1. Background and Importance

The information on animal biological resources at Sand Creek Massacre National Historic Site (NHS) is incomplete. The purpose of this section is to summarize existing information based on two recent studies (Sovell et al. 2008 and Tilmant et al. 2006).

Sand Creek Massacre NHS is a small patch of prairie habitat surrounded by agriculture. The primary habitat at Sand Creek NHS is shortgrass prairie and sandsage shrubland with the intermittent Big Sandy Creek, and its associated riparian vegetation, bisecting the site. Shortgrass prairie is home to several candidates for federal endangered or threatened species status and several State of Colorado listed species(Sovell et al. 2008).

The pools of the Big Sandy Creek running through the Historic Site contain suitable habitat for the Arkansas darter (*Etheostoma cragini*). Populations of this fish occur as isolated colonies within specialized habitat and are susceptible to extirpation due to drought and ground water loss (Tilmant et al. 2006). Because of its vulnerability to extirpation, the Arkansas darter is a species of concern (with numerous rankings and designations by conservation organizations), and it would be important to know if the fish was found within the Historic Site.

The Southern Plains Inventory & Monitoring Network (SOPN) determined that an inventory of the biological resources was needed; based on the habitats, and the plants and animals known to inhabit the surrounding region, nine priority species were targeted for inventory (Sovell et al. 2008). This information is intended to inform management plans and monitoring programs, especially with regard to species that are sensitive to grazing practices (including the lack of grazing), since all grazing has ceased in the area.

4.13.2. Data and Methods

This limited assessment is based on a rare species inventory conducted by the Colorado Natural Heritage Program (CNHP)(Sovell et al. 2008) and a trip report from the National Park Service (NPS) Water Resources Division (Tilmant et al. 2006) describing fisheries sampling conducted in five pools.

The only indicator used for this assessment is presence/absence; see Table 4.13.2-1.

Table 4.13.2-1. Summary of the rare vertebrate presence/absence indicator and its contribution to the overall natural resource condition assessment.

Indicator	Description of How the Indicator Contributes to the Overall Resource Condition	General Contribution of this Indicator to the Overall Resource Condition
Presence/absence	The presence of rare vertebrate species may represent a beginning point for future condition assessment.	The presence of rare vertebrate species at the Historic Site is a starting point for monitoring, particularly related to habitat needs and management practices. Insufficient information exists at this time to warrant a condition rating other than unknown.

4.13.3. Reference Conditions

No references conditions were developed for this resource topic.

4.13.4. Condition and Trend

Updated information on landbirds (see section 4.11) and prairie dogs (see section 4.12) are presented earlier in this chapter.

As part of the rare species inventory, the Arkansas darter (*Etheostoma cragini*), swift fox (*Vulpes velox*), and Texas horned lizard (*Phrynosoma cornutum*) were surveyed for, but not observed. Areas that appear suitable for the swift fox do exist on the Historic Site, and may warrant additional sampling in the future (Sovell et al. 2008).

The NPS WRD also did not find the Arkansas darter during their sampling in 2006 (Tilmant et al. 2006). It may still be possible, however, that the darter could occupy one or more of the Big Sandy Creek open-water pools during summer months. Flood events might also move Arkansas darters in and out of park pools (Fran Pannebaker, pers. comm. July 24, 2013). Because of the limited sampling to date, and changing condition of the pools, additional sampling is warranted.

4.13.5. Sources of Expertise

No experts were consulted for this resource topic.

4.13.6. Literature Cited

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USGS

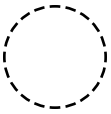
The Arkansas darter was not found during sampling, but additional sampling is warranted.

4.14. Aquatic Invertebrates

Indicators/Measures

- Presence/absence of invertebrate species

Condition – Trend - Confidence



Insufficient Data - Insufficient Data - Low

4.14.1. Background and Importance

Although aquatic insects from the Great Plains region of Colorado have been documented in statewide surveys, their records remain incomplete. This section summarizes a study conducted in 2009 at Sand Creek Massacre National Historic Site (NHS) that documented aquatic insects found in the Big Sandy Creek.

The Big Sandy Creek is an ephemeral drainage in southeast Colorado that flows through Sand Creek Massacre NHS. Stream flow only occurs in certain reaches during major precipitation events in the spring and summer. The stream is usually dry throughout the winter, except for small pools. The flood plain is shallow and wide through most of the creek's extent, with short sections of gallery forest composed of Great Plains cottonwood (*Populus deltoides* var. *occidentalis*). Within the Historic Site, the creek has a number of pools, that vary in depth, and are oftern surrounded by cattail (T*ypha latifolia* L.)

4.14.2. Data and Methods

This limited assessment is based on a single aquatic invertebrate study conducted by Colorado State University in May-September 2009 (Kondratieff and Durfee 2010). The methods used in that study included monthly sampling of aquatic habitats using aerial nets, aquatic D-frame dipnets, black light traps, and bottle traps.

The only indicator used for this assessment is presence/absence; see Table 4.14.2.-1.

4.14.3. Reference Conditions

No reference conditions were developed.

4.14.4. Condition and Trend

A total of 107 distinguishable taxa were collected representing six orders and 27 families (Appendix X). Many of the species found are common in Colorado, or regionally to the eastern part of the state. Highlighted below are the species from the Odenata family that are of special note.

The Black-fronted Forktail (*Ischnura denticollis* Burmeister) is considered a damselfly of western marshes and springs and is uncommon in Colorado.

The Bleached Skimmer (*Libellula composita* Hagen) is a localized species of eastern Colorado and regionally uncommon in Colorado; it was common at the Historic Site. It was also noted in Sovell et al.'s (2008) inventory of rare species. The dragonfly was ranked a G3S1, according to the Colorado Natural Heritage Program, noting that it is globally vulnerable (G3) and critically imperiled at the state level (S1) because of rarity (five or fewer occurrences in the state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction.

4.14.5. Sources of Expertise

The inventories completed by Kondraitieff et al. (2010) and Sovell et al. (2008) served as the basis for this resource topic assessment.

4.14.6. Literature Cited

Kondraitieff, B. C. and R. S. Durfee. 2010. Aquatic insects (Ephemeroptera,



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Figure 4.14.1-1. The Black-fronted Forktail damselfly is uncommon in Colorado.

Table 4.14.2-1. Summary of the aquatic insect indicator and its contribution to the overall natural resource condition assessment.

Indicator	Description of How the Indicator Contributes to the Overall Resource Condition	General Contribution of this Indicator to the Overall Resource Condition
Presence/absence	The presence of aquatic insects, and particularly several uncommon species, is interesting, however, there is insufficient information to put this occurrence into context for greater meaning. The aquatic insect survey may represent a beginning point for future condition assessment.	The presence of several uncommon aquatic insects at the Historic Site is interesting, however, no additional information has been gathered to provide additional context for its occurrence. Insufficient information exists at this time to warrant a condition rating other than unknown.



ARIZONA DRAGONFLY

Figure 4.14.1-2. The Bleached Skimmer dragonfly was commonly found in Sand Creek Massacre NHS, though it is uncommon and critically imperiled in Colorado.

Odenata, Hemiptera, Coleoptera, Trichoptera, Diptera) of Sand Creek Massacre National Historic Site on the Great Plains of Colorado. *Journal of the Kansas Entomological Society* 83(4):322-331.

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NRCA field meeting at Sand Creek Massacre NHS.

Chapter 5: NRCA Discussion and Connection to *State of the Park* Reporting

5.1. Introduction

The purpose of this chapter is to provide a summary of the natural resource topics assessed for Sand Creek Massacre National Historic Site's NRCA. The format will be closely aligned to the *State of the Park* report to aid the integration of natural resource condition information derived from this NRCA into the park's *State of the Park* report.

State of the Park

As part of the stewardship of national parks for the American people, the NPS has begun to develop *State of the Park* reports to assess the overall status of each park's resources. The NPS will use the *State of the Park* report information to improve park priority setting and to synthesize and communicate complex park condition information to the public in a clear and simple way (NPS 2011a,b).

The key purposes of each *State of the Park* report is to:

- Provide to visitors and the American public a snapshot of the status and trend in the condition of a park's priority resources and values.
- Summarize and communicate complex scientific, scholarly, and park operations factual information and expert opinion using non-technical language and a visual format.
- Highlight park stewardship activities and accomplishments to maintain or improve the *State of the Park*.
- Identify key issues and challenges facing the park to help inform park management planning.

In this chapter, we will address three of the four *State of the Park* purposes by providing an overall natural resource summary table showing the resource topic condition findings, which is based on the hierarchical framework discussed in Chapter 3. The Status and Trend symbols used in the resource summary table, and throughout this report, can also be found in Chapter 3, Table 3.2.3-1.

The background color, in green, yellow, or red, represents the current condition, the direction of the arrow summarizes the condition's trend, if any, and the thickness

of the outside line represents the degree of confidence in the assessment of the resource.

The Historic Site's *State of the Park* natural resource summary is shown in Table 5.1-1. The rationale provides an explanation for the overall condition of each resource topic assessed for the Historic Site's NRCA. The internet version of this NRCA report is available at http://www.nature.nps.gov/water/nrca/reports.cfm.

In section 5.2, we summarize each natural resource topic by individual indicators and assign condition status, along with a brief review explaining the rationale for the resource condition. We also include a resource brief, summarizing key information pertaining to each natural resource topic. Sections 5.3 and 5.4 discuss noteworthy natural resource condition highlights and key issues and challenges for consideration in management planning, respectively. All of the sections in Chapter 5 are intended to be used as a stand-alone document to aid the Historic Site staff in developing the natural resource component of their *State of the Park* report.

Table 5.1-1 *State of the Park* Natural Resource Summary Table

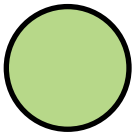
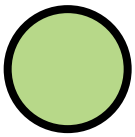
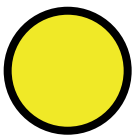
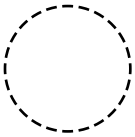
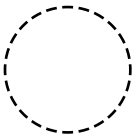
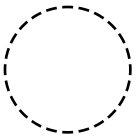
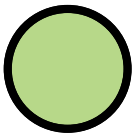
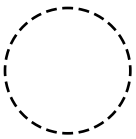
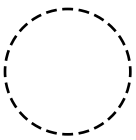
Priority Resource or Value	Condition Status/Trend	Rationale
Natural Resources		
Viewshed		The natural topography and vegetation communities, primarily grasslands and riparian, are dominant influences on the viewshed and contribute and the sense of place is largely retained. There has been some development both within and outside the site that can detract from the sense of place, but such development tends to be the middle ground and background of the viewshed and remains relatively inconspicuous.
Night Sky		All-sky Anthropogenic Light Ratio, zenith sky brightness, limiting magnitude, and Bortle Dark-Sky Scale measures were used to assess the night sky. The Bortle Dark-Sky Scale and limiting magnitude measures resulted in a "rural sky" but some air glow was observed. The site had a near natural lightscape for the sky brightness measure, but had a minor amount of anthropogenic light from a neighboring farm. In general, the night sky is rural, with minimal surrounding development and associated light sources.
Soundscape		The majority of sounds heard are derived from nature, including birds, wind, and quiet. In addition, the types of noises heard and their associated loudness are expected for the variety of designated uses that occur throughout the Historic Site. The additional noise characteristics such as pitch or duration do not detract from the soundscape's good condition. The primary detriment to soundscape quality is commercial jet overflights flying to and from Denver International Airport.
Air Quality		Air quality monitoring is multifaceted and includes visibility, ozone, and wet deposition for total nitrogen and total sulfur. Three of the four air quality condition indicator values warranted moderate concern. Only wet deposition of sulfur was consideration to be within a level to warrant a good condition rating. No trend can be derived due to the lack of any nearby monitoring stations.
Geology		A geoarchaeological assessment was completed in 1999; no geological assessment has been conducted.
Surface Water		No surface water data or monitoring program exist for the Historic Site.

Table 5.1-1 State of the Park Natural Resource Summary Table (continued)

Priority Resource or Value	Condition Status/Trend	Rationale
Groundwater		The NPS Water Resources Division installed twelve water level monitoring wells along the ponds along Big Sandy Creek within the Historic Site. The wells were installed in 2011 and have been operational for approximately 18 months. Data from the recorders have not yet been downloaded and analyzed. The data from the wells will be used for baseline and long-term monitoring for the Historic Site's groundwater resource.
Riparian Habitat		A proper functioning condition for riparian areas requires integration between water flow and floodplain characteristics, vegetation types and amounts, and erosion and sediment deposition processes. All of these aspects are properly functioning throughout the Historic Site' riparian habitat areas and supporting the system's resiliency.
Grasslands		Shortgrass prairies at Sand Creek are dominated by native, perennial, C4 grasses as expected for healthy prairies. Although exotic plants are certainly present at Sand Creek they do not dominate the landscape as they do in many other grasslands. The CRP areas have a bit of a departure from the historic shortgrass communities, but they too are at least functioning as healthy grasslands, and probably do not warrant much concern.
Exotic Plants		Several factors contribute to the exotic plants condition, including types of exotic, control difficulty, and the location where the plants are growing. Even though the Historic Site has a few ecologically threatening plants, such as the non-native bromes, the majority of the non-natives are growing along the high vector corridors and have not invaded the interior areas of the Historic Site. In addition, in over 57% of park-wide plots surveyed, no exotics were found, warranting a good condition.
Landbirds		We used one indicator/measure, species occurrence, in three separate contexts (temporal, spatial, and conservation), to assess the condition of landbirds. A total of 72 bird species have been reported at the Historic Site, with 50 of them being detected in recent (2009-2012) surveys. With the exception of the Burrowing Owl, which has not been detected since the disappearance of black-tailed prairie dogs at the Historic Site (in 2010), we consider the condition of landbirds at the Historic Site to be good. We do not have sufficient data to justify a trend in the condition at this time.
Prairie Dog		We used one indicator/measure, area occupied and density, to assess the condition of black-tailed prairie dogs. Acreages occupied and prairie dog densities were estimated for both prairie dog colonies in some years from 2001-2009. However, in early 2010 the sylvatic plague decimated the colonies in and adjacent to the Historic Site. From an ecological standpoint, the condition of the black-tailed prairie dog is of significant concern. The trend is unchanging at this time; the condition had deteriorated in 2010, when the population was reduced to zero. The population cannot deteriorate further from that point, and there is no evidence of an increase at this time.
Rare Vertebrates		Based on habitat, the swift fox, Arkansas darter, and Texas horned lizard may use Sand Creek Massacre Historic Site. While some species of concern were documented at the site, these species were not, although habitat conditions suggest they are likely and additional sampling may be warranted. The presence of rare vertebrate species represents a beginning point for future condition assessment.
Aquatic Invertebrates		The presence of aquatic insects, and particularly several uncommon species, is interesting, however, there is insufficient information to put this occurrence into context for greater meaning. The aquatic insect survey may represent a beginning point for future condition assessment.

5.2. *State of the Park* – Natural Resources

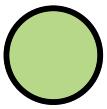
Our NRCA assessment of each natural resource topic assessed for Sand Creek Massacre NHS is based on a synthesis of the park's monitoring, evaluation, and management programs, as well as expert opinions and other credible scientific literature and/or programs. Copies of references and website links to sources used to assess each resource topic are provided on a DVD with the final NRCA report.

The overall assessment of the condition for a Priority Resource or Value may be based on a combination of the status and trend of multiple indicators and specific measures of condition shown in the tables below.

Viewshed			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Scenic and Historic Integrity	Housing density TBD		Housing densities surrounding the Historic Site are relatively low, with > 80% of the square km units being undeveloped
	Road density TBD		Road densities are also relatively low, with the majority of the area surrounding the Historic Site having < 3 km of roads per square km
	Conspicuousness of noncontributing features		There has been some development both within and outside the site that can detract from the sense of place, but such development tends to be the middle ground and background of the viewshed and remains relatively inconspicuous.
Intactness TBD	The degree to which the viewshed is unaltered from its 1864 reference state		Despite some development, the natural topography and vegetation communities, primarily grasslands and riparian, are dominant influences on the viewshed and contribute and the sense of place is largely retained.

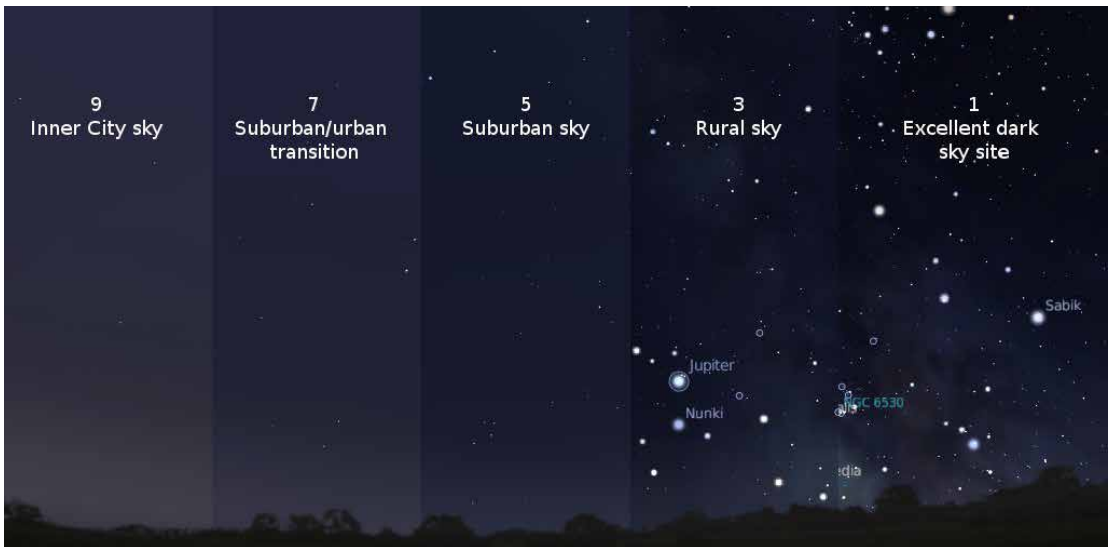
Resource Brief

The viewshed condition at Sand Creek Massacre NHS is considered good. There has been some development both within and outside the site that can detract from the sense of place, but such development tends to be the middle ground and background of the viewshed and remains relatively inconspicuous. The site's administrative buildings are well shielded and blend with their surroundings, and the agricultural and rural development does not dominate the viewshed and is not sufficient so as to detract significantly from the site's sense of place.

Night Sky			
Indicators of Condition	Specific Measures	Condition Status/ Trend	Rationale
Sky Brightness	All-sky Anthropogenic Light Ratio		The NPS Night Sky Program collected ALR data in January 2010 with a value of 0.20, indicating good condition.
	Zenith Sky Brightness		A sky quality meter was used to measure zenith sky brightness and reported values were consistent with a near natural nightscape except for one light source from a nearby farm, which impacted dark adaptation.
Sky Quality	Limiting Magnitude		The limiting magnitude yielded a value of 7.0, which is consistent with the value assigned using the Bortle scale, suggesting a rural sky in good condition.
	Bortle Dark-Sky Scale		The features of the night sky appeared complex, very few light domes were evident, but some bright natural air glow was visible resulting in a "rural sky." This is a Bortle Dark-Sky Scale Class 3, which is considered to be in good condition.

Resource Brief

Natural dark skies are a valued resource for many reasons; they are an important factor for maintaining healthy biological systems and have an aesthetic appeal for recreational value. Night skies, and the objects that can be seen, also have strong cultural connections. For thousands of years, people have watched the night sky and told stories connected to the stars, planets, and constellations that they observe. The night sky at Sand Creek Massacre NHS is consistent with what one would expect to see in a rural area, away from the lights of the city. The Milky Way is clearly defined, and many star clusters, nebulae, and other celestial objects can be seen; although some ambient light pollution can be detected from the surrounding rural landscape and distant cities.



Composite image illustrating the range of night sky conditions based on the Bortle Dark Sky Scale.

Soundscape			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Amount of Acoustical Environment Comprised of Natural Sound vs. Anthropogenic Noise	Percent of Sound Types and Audibility		During the summer, birds, wind, and noise-free intervals comprised almost 69% of the sound sources. In winter, the same sources comprised 67% of the sounds sources. On-site analysis revealed that jets were the most commonly heard noise.
Are types of sounds consistent with designated park uses?	Types of Noises or Natural Sounds		The types of sounds heard were predominantly nature sounds, including birds, insects, and wind. The primary anthropogenic sound was from aircraft-primarily commercial jets flying to and from Denver International Airport.
Characteristics of Anthropogenic Noise	Loudness, pitch, occurrence, and duration		The sound characteristics were such that didn't detract from the condition of the soundscape. Often times, masking of noises would occur as a result of biologic activity, especially throughout the summer monitoring period.

Resource Brief

Visitors to national parks often indicate that an important reason for visiting the parks is to enjoy the relative quiet. In a 1998 survey of the American public, 72% of respondents identified opportunities to experience natural quiet and the sounds of nature as an important reason for having national parks (Haas and Wakefield 1998). Additionally, 91% of NPS visitors "consider enjoyment of natural quiet and the sounds of nature as compelling reasons for visiting national parks" (McDonald et al. 1995). Cultural activities are also considered to contribute to a good soundscape condition and are desirable at cultural parks. The soundscape at the Historic Site is primarily comprised of natural sounds. Most of the anthropogenic noises heard during acoustical monitoring were consistent with designated Historic Site uses thus relatively unobstrusive. The exception was noise heard from commercial jets flying to and from Denver International Airport, but even that noise did not detract from the overall good condition of the soundscape. In addition, there were times when the soundscape at the Historic Site was so quiet that it was below the acoustical monitoring equipment's ability to record any sound at all.



NPS

Cheyenne Healing Run in 2006.

Air Quality			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Air Quality	Visibility Haze Index		Five-year average of interpolated visibility values were derived to determine that the condition of visibility is of moderate concern at the Historic Site.
Air Chemistry 	Level of Ozone		Five-year average of interpolated ozone values were derived to determine that the condition of ozone is of moderate concern at the Historic Site. In addition, a total of two plants have been identified as ozone sensitive, four of which serve as bioindicators.
	Atmospheric Wet Deposition in Total N		Five-year average of interpolated atmospheric wet deposition values were derived to determine that the condition of total nitrogen is of moderate concern at the Historic Site.
	Atmospheric Wet Deposition in Total S		Five-year average of interpolated atmospheric wet deposition values were derived to determine that the condition of total sulphur is good at the Historic Site.

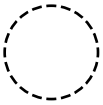
Resource Brief

Air quality doesn't just affect the air we breathe, it also affects many air quality related values such as visibility and cultural and natural resources. There are different facets to air quality monitoring including ozone levels, visibility conditions, and wet deposition levels. Currently, all levels, with the exception of wet deposition for total sulfur, warrant a moderate concern condition at the Historic Site. These values are based upon 5-year interpolated averages since no on-site monitoring occurs within or in close proximity to the Historic Site. The Historic Site contains two ozone-sensitive plant species, Indianhemp and Groundnut, with latter serving as an ozone bioindicator. Bioindicator species are more likely to exhibit ozone damage before other species are impacted by higher ozone levels. The Historic Site's air quality is largely influenced by activities and operations that occur outside its boundary, and the future condition of its air quality condition is ultimately dependent on local, regional, and national planning.



NPS

Air quality affects visibility and cultural and natural resources.

Geology			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
None	None		None

Resource Brief

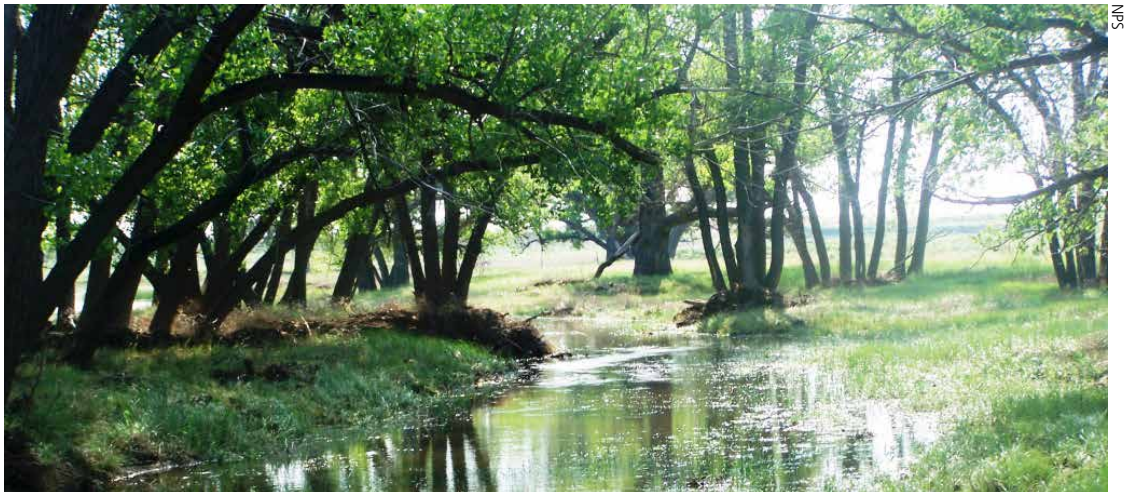
Geology, and associated soils, are the basis for the hydrology, the basic landforms, and topography for an area, that then support the biotic communities. Soils, hydrology, and landform influence human settlement patterns, and how people use the land--for farming, ranching, hunting, fishing, and other basic land uses. Landforms such as knolls, ridges, and the river also figured prominently in the historical events of the massacre.

Sand Creek Massacre NHS is located in the Big Sandy drainage in southern Colorado. The topography consists of gently undulating hills comprised of sand plains stabilized by vegetation, dunes of aeolian deposits, and smooth plains. It is bisected by Big Sandy Creek and north and east of the creek the landscape is dominated by smooth plains where grassland occur. The Sand Creek valley is carved out of thick marine Cretaceous shale including the Pierre Shale, Niobrara Formation, and Carlile Shale. The formations may be up to 4,000 feet thick. In the Historic Site area, the Cretaceous rocks are buried by Quaternary (ranging in age from about 2 million years old to recent) deposits, primarily loess and aeolian sand. The Late Cretaceous rocks are located in limited exposures east and northeast of Big Sandy Creek. South and west of Big Sandy Creek is Quaternary age dune sand, comprised of approximately 75% very fine to medium sand and 25% coarse sand. Big Sandy Creek and its tributaries' riparian corridor is comprised of Quaternary alluvium deposits that underwent successive periods of deposition and erosion, resulting in at least four terraces above the current floodplain. More modern floodplain deposits are reflected in three terraces deposited within the past 2,500 years.

Surface Water			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Water Quality	pH		No data pertaining to pH have been collected at the Historic Site.
	Dissolved Oxygen		No data pertaining to dissolved oxygen have been collected at the Historic Site.
	Temperature		No data pertaining to temperature have been collected at the Historic Site.
	Specific Conductance		No data pertaining to specific conductance have been collected at the Historic Site.
	Turbidity		No data pertaining to turbidity have been collected at the Historic Site.

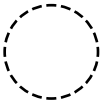
Resource Brief

Running water and pools of the Big Sandy Creek provide water in an otherwise arid landscape, making water a unique resource at the Historic Site. Perennial streams are among the most critical and impacted natural resources of the Southern Plains. The presence and extent of surface water has traditionally provided a focus for human habitation in the region, resulting in cultural significance coincident with reliable and abundant rivers, streams, wetlands, and springs. Core water quality parameters reflect the function of the physical and biological environment with which water interacts. The core parameters—temperature, specific conductance, turbidity, pH, and dissolved oxygen—are easily measured and constitute a means of characterizing potential stressors to the health of aquatic systems. At this time, no surface water monitoring has been implemented at the Historic Site.



NPS

Big Sandy Creek runoff in 2007..

Groundwater			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale for Resource Condition
Groundwater	Change in groundwater level		None

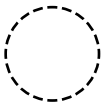
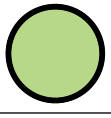
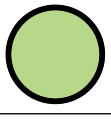
Resource Brief

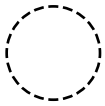
Groundwater accounts for 1.7% of Earth's total water and 30.1% of Earth's freshwater (USGS 2011). The overall trend in the United States is that as population increases, the amount of groundwater withdrawn also increases.

Long-term water-level declines caused by sustained groundwater pumping are a key issue associated with groundwater use, and many areas of the United States are experiencing groundwater depletion. Groundwater resources supply approximately 18% of Colorado's water supply needs (Colorado Geological Survey 2013). With streams being sparse throughout Colorado's eastern plains, groundwater use is higher compared to surface water withdrawals. Groundwater withdrawal accounts for nearly 100% of use in Kiowa County (Colorado Geological Survey 2013).

Most of the Sand Creek Massacre NHS aquifer area is covered by a thin layer of Quaternary deposits that are made up of sand, gravel, silt, and clay deposited by wind and streams (Martin 2006). These deposits are made up of three groups: terrace deposits that are higher than the stream level (primarily east of Big Sandy Creek); dune sand (primarily west of Big Sandy Creek); and valley-fill deposits along streams. The layer, which is permeable, is a few tens of feet thick. Beneath the Quaternary deposits are rocks from the Late Cretaceous period, approximately 80-85 million years old. The Cretaceous bedrock formations, several thousand feet thick, are relatively impermeable and generally pose a barrier to the downward movement of groundwater. Rainfall infiltrates the permeable Quaternary deposits and accumulates above the Cretaceous formations, forming a shallow, perched aquifer. Groundwater in the Quaternary formations is recharged by rainfall.

The NPS Water Resources Division installed twelve water level monitoring wells along the ponds along Big Sandy Creek within the Historic Site (Karl Zimmermann, pers. comm., Kevin Noon, NPS, pers. comm.). The wells were installed in 2011 and have been operational for approximately 18 months. Data from the recorders have not yet been downloaded and analyzed. The data from the wells will be used for baseline and long-term monitoring of the Historic Site's groundwater resource.

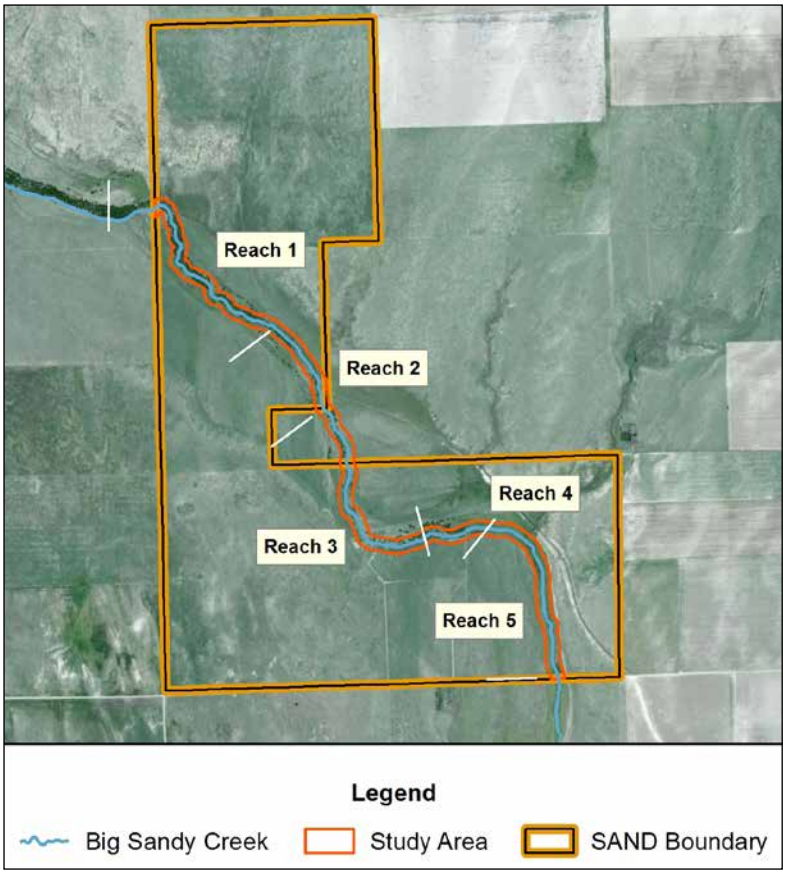
Riparian Habitat			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Hydrology	Floodplain		The relatively recent flood debris above banks and observations by park staff indicate that Big Sandy Creek is flowing and flooding lower floodplain terraces at its potential frequency.
	Beaver dams		No beaver dams exist along the portion of Big Sandy Creek that runs throughout the Historic Site.
	Sinuosity, width/depth ratio, and gradient		The sinuosity, width/depth ration, and gradient all appear to be in balance with landscape setting.
	Riparian wetland area		Riparian zone is near or at potential extent. Plains cottonwoods occupy most of the lower terraces in most of the reaches. Sinuosity is reestablishing in a slightly incised channel along reach #2, resulting in a widening riparian-wetland zone at this lower elevation.
	Upland watershed		No evidence of excessive sediment inputs or adverse changes to channel form were observed suggesting potential issues in the upland watershed.
Vegetation	Age class distribution of riparian wetland vegetation		Presently three age classes of Plains cottonwood dating back to 1865 were present, but no recruitment for the cottonwoods has occurred since the 1950s. Regardless, this indicator is still considered good.
	Diverse vegetation composition		Plains cottonwood is essentially the only woody species present but is absent throughout some of the stream reaches. However, a diverse, vigorous, soil-binding herbaceous plant community is likely to maintain channel stability in frequent to moderately frequent floods
	Soil moisture characteristics		Plant species present were indicative of moist conditions, and a rising water table may be possibly due to Tamarisk removal.
	Plants have root masses capable of withstanding high streamflow events		All species present are rhizomatous with root masses capable of withstanding frequent to moderately frequent flood flows, though probably not the very large, infrequent floods believed to be associated with cottonwood establishment.
	Vigorous plants		Cottonwoods appeared healthy along some reaches and were showing signs of decadence along others. The herbaceous communities exhibited strong vigor, and upland species are not invading riparian zone
	Vegetation cover		Greater than 90% native cover on >90% of banks along all reaches was observed.
	Plant communities are coarse and/or large		No coarse and/or large woody debris was found (nor expected to be found) along the portion of Big Sandy Creek that runs throughout the Historic Site.
Erosion/Deposition	Floodplain and channel characteristics		In certain reaches the channel was more incised but in general was considered "on-grade". No evidence of adverse changes to channel form was observed along any of reaches.

Riparian Habitat			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Erosion/Deposition continued	Point bars		No beaver dams exist along the portion of Big Sandy Creek that runs throughout the Historic Site.
	Lateral stream movement		Lateral movement is related normal stream sinuosity and has occurred within the active floodplain as is evidenced by the distribution of cottonwood trees and older fluvial terraces.
	Vertical stability		No evidence of vertical instability was observed throughout all reaches.
	Balance of water and sediment		No evidence of excessive sediment inputs or adverse changes to channel form was observed throughout all reaches.

Resource Brief

Riparian wetlands are a type of non-tidal wetland formed along river and stream floodplains. These wetlands serve many functions including water purification, flood control, buffering riverbank erosion, habitat for numerous wildlife, fish, shellfish, and plant species, and also provide many recreational opportunities. In the arid west, riparian habitat is often in marked contrast with the surrounding terrestrial vegetation and is strongly influenced by the presence or absence of water (NPS-WRD 2011).

An interdisciplinary team of experts from NPS' Water Resources Division and Southern Plains Inventory and Monitoring Network conducted a qualitative riparian habitat assessment at the Historic Site along Big Sandy Creek (Martin et al. 2012), using "A User Guide to Assessing the Proper Functioning Condition and the Supporting Science for Lotic Areas" developed by Prichard et al. (1998). This assessment included three main categories including hydrology, vegetation, and erosion/deposition. A total of 17 common attributes and processes within each of these three categories was assessed.



Big Sandy Creek was divided into five separate reaches for the purposes of the riparian assessment.

Big Sandy Creek was divided into 5 separate reaches and, all indicators, throughout all reaches, were considered to be in good condition and trend is unknown at this time.

Grasslands			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Hydrology Soil/Site Stability and Hydrologic Function	Rills		Condition did not deviate substantially from that which would be expected for the site.
	Water Flow Patterns		Condition did not deviate substantially from that which would be expected for the site.
	Pedestals and/or terracettes		Condition did not deviate substantially from that which would be expected for the site.
	Bare ground		Condition did not deviate substantially from that which would be expected for the site.
	Gullies		Condition did not deviate substantially from that which would be expected for the site.
	Wind-scoured, blowout and/or depositional areas		Condition did not deviate substantially from that which would be expected for the site.
	Litter Movement		Condition did not deviate substantially from that which would be expected for the site.
	Soil surface resistance to erosion		Condition did not deviate substantially from that which would be expected for the site.
	Soil surface loss or degradation		Condition did not deviate substantially from that which would be expected for the site.
	Compaction layer		Condition did not deviate substantially from that which would be expected for the site.
Biotic Integrity	Species Composition, Landscape-scale Diversity		The patterns of plant community distribution generally match that of the ecological sites and soils.
	Species Composition, Local scale		Local species composition was primarily native species that would be expected for the sites, given their soils and disturbance history.
	Response of Annual Species to Disturbance		Grasses were nearly all perennial, indicating stability. Forbs were considerably more variable among sites and years, but also tended to have a high proportion of perennial species.

Grasslands			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Biotic Integrity (continued)	Relative proportion of functional groups (e.g., graminoid, forbs, shrubs, etc.)		The proportions of functional groups observed in our grassland monitoring did not entirely match those reported in the ecological site descriptions and showed some annual variability among years, however they were not unexpected given the site characteristics and disturbance history.
	Relative proportion of C3 and C4 species.		Sites were dominated by C4 grasses which is exactly what would be expected in a healthy shortgrass prairie.

Resource Brief

Based on the indicators, data, and expert opinion, we consider the overall condition of the grasslands at Sand Creek Massacre NHS to be in good condition. Shortgrass prairies are typically dominated by perennial C4 grasses, which is the case at Sand Creek. Although exotic plants are certainly present at Sand Creek they do not dominate the landscape as they do in many other grasslands. The CRP areas have a bit of a departure from the historic shortgrass communities, but they too are at least functioning as healthy grasslands, and probably do not warrant much concern. Similarly, areas with previous, and possibly future, prairie dog activity represent a departure from historic climax communities, but they are also within the realm of what would be expected on these sites based on NRCS state and transition models for areas with such disturbance.

Exotic Plants			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Exotic Plant Presence	Significance of Impact		Ranking the highest in significance of impact were the field bindweed, Kentucky bluegrass, cheatgrass, and yellow/ white sweetclovers. Cheatgrass is well known for its ability to dramatically change an ecosystem sometimes irreversibly. Field bindweed is an aggressive competitor, especially during dry conditions.
Exotic Plant Ease of Control	Feasibility of Control		A variety of species ranked highly infeasible to control including field bindweed, prickly Russian thistle, yellow/white sweetclovers, however, this indicator may not reflect the effort needed for control. For example, field bindweed is for the most part isolated to growing along the shoulders of the roads throughout the historic, making it much easier to control.
Exotic Plant Location	Proportion of High Priority Blocks Infested		Prickly Russian thistle and Kochia were by far the most widespread throughout the high priority blocks, with 56% and 49% detection rates, respectively.
	Proportion of Interior Blocks Infested		More than half (57%) of the blocks surveyed for exotics were exotics-free! Of the exotics detected, Kochia and prickly Russian thistle were the highest at 26% and 23%, respectively, indicating that they may be more confined to the road and trail corridors.
Exotic Plant Distribution	Distribution of High Priority Species		Known distributions of the highest ranked species were mapped. Overall, the sweetclovers and kochia appear to be the most widely distributed throughout the Historic Site.

Resource Brief

The negative impact exotic plants have on native ecosystems is well documented and most parks are faced with dire circumstances when it pertains to their ability to control and manage these pests. This is certainly not the case at the Historic Site. In fact, the condition of exotic plants is considered good across all five indicators. The majority of the invasive plants are found along the high vector corridors, including roads and trails. In addition, the majority of exotic species are easily controlled due to their biologic characteristics as well as the fact that most have not become established throughout the interior of the Historic Site. In fact, the entire Historic Site was surveyed for exotics, and in 57% of all plots sampled no exotics were found! That warrants a very good current condition for exotic plants at the Historic Site.



NPS

Exotic plant management efforts at Sand Creek Massacre NHS..

Landbirds			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Temporal Context		Of 64 bird species detected at the Historic Site in 2005 or 2006, 42 were detected in recent surveys (in 2009-2012). Twenty-two were not detected in recent surveys. However, each of the 22 species were either outside of their normal breeding range or breeding habitat for them only "possibly exists" at the Historic Site.
	Spatial Context		Forty-one species were observed during 2001-2005 regional surveys that have the potential to occur at the Historic Site but were not detected during recent surveys at the park. However, only 16 of the 41 species are within their normal breeding ranges. Of the 16 species, 12 are in the "limited to none" breeding habitat class and four are in the "possibly exists" class. Therefore, there is no particular concern with having not observed these 41 species during recent surveys at the park.
	Conservation Context		Eighteen native species that have been reported to occur at the Historic Site are listed by one or more organization as being of conservation concern. Of these, we consider seven species to have high conservation potential at the park; these are species that are within their normal breeding range and have sufficient habitat at the Historic Site to support their breeding. All of the seven species have been observed during all four years of recent surveys (2009-2012), except for the Burrowing Owl, which was not detected in 2010-2012 (since the black-tailed prairie dog population crashed). The condition of species of conservation concern is good, except that some concern exists for the Burrowing Owl (and to a lesser extent, the Mountain Plover).

Resource Brief

Landbirds are a conspicuous component of many ecosystems, and changes in landbird populations may be indicators of change in the biotic or abiotic components of the environment upon which they depend (Canterbury et al. 2000; Bryce et al. 2002). Landbirds are also highly detectable and can be efficiently surveyed with the use of numerous standardized methods (Bibby et al. 2000; Buckland et al. 2001). In addition to being good indicators of ecosystem change, landbird communities are inherently valuable. The condition of landbirds at the Historic Site was assessed using one indicator/measure—species occurrence (presence/absence). We evaluated species occurrence in three contexts: a temporal context, a spatial context, and a conservation context. The primary sources of information for the assessment were annual breeding season surveys conducted by Rocky Mountain Bird Observatory (RMBO) in 2009-2012, a bird inventory and survey by RMBO in 2005, a rare vertebrate species inventory by the Colorado Natural Heritage Program in 2006, and surveys conducted by RMBO in the surrounding region in 2001-2005. A total of 72 bird species have been reported to occur at the Historic Site, with 50 of the species occurring within their primary breeding ranges. The temporal species occurrence comparison found that, of 64 bird species detected at the Historic Site in 2005 or 2006, 42 were detected in recent surveys. Twenty-two were not detected in recent surveys. However, each of the 22 species were either outside of their normal breeding range or breeding habitat for them only "possibly exists" at the Historic Site. The spatial comparison found that 41 species were observed during the 2001-2005 RMBO regional surveys that have the potential to occur at the Historic Site but were not detected during recent RMBO surveys at the Historic Site. However,

based on the status of their breeding ranges and breeding habitat preferences, we do not have any concerns with the list of 41 species. Eighteen native species that have been reported to occur at the Historic Site are listed by one or more organization as being of conservation concern. Of these, seven species are considered as having high conservation potential; these are species that are within their normal breeding range, and sufficient habitat exists at the Historic Site to support their breeding. All of the seven species have been observed during all four years of recent surveys, except for the Burrowing Owl. This species has not been observed in the three most recent years of surveys (2010-2012); the species has not been detected since the time that the black-tailed prairie dog population was decimated at the Historic Site. We consider the condition of species of conservation concern to be good, except that some concern does exist for the Burrowing Owl. Overall, the condition of landbirds at the Historic Site is good. Adequate information does not exist at this time to evaluate trends in the condition.



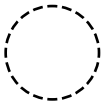
NPS - ROBERT BENNETTS

Burrowing owls at Sand Creek Massacre NHS.

Prairie Dog			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Area occupied and Density of prairie dogs	Area occupied		The north colony decreased from 9.88 acres occupied in 2009 to 0 acres in 2010. The south colony decreased from 153.20 acres occupied in 2009 to 0 acres in 2010. The sylvatic plague is thought to have killed all prairie dogs in and adjacent to the Historic Site in early 2010, and no prairie dogs have been observed since that time.
	Prairie dog density		The density of prairie dogs in the north colony decreased from 13.3 prairie dogs per acre (measured in 2006) to 0 in 2010. The density in the south colony decreased from 17.8 prairie dogs per acre in 2009 to 0 in 2010. The sylvatic plague killed prairie dogs in the north and south colonies in early 2010, and no prairie dogs have been observed at the Historic Site since that time.

Resource Brief

Prairie dogs are an important component of the ecosystems they inhabit. They directly and indirectly influence grasslands through their grazing and burrowing and as prey (Kotliar et al. 2006). Through their foraging and clipping of vegetation to maintain their habitat, as well as the mixing of subsoil and topsoil during excavations, prairie dogs affect the redistribution of minerals and nutrients, encourage penetration and retention of moisture, and affect plant species composition (Kotliar et al. 2006). Prairie dog burrows and colony-sites provide shelter and nesting habitat for a variety of animals (e.g., burrowing owls), and many animals prey on prairie dogs (e.g., American badgers, bobcats, ferruginous hawks). In early 2010, the black-tailed prairie dog colonies on the Historic Site were decimated by sylvatic plague, with no apparent survivors. As of early 2013, the colonies have not returned. However, because of the significant ecological role that prairie dogs play in the landscape, and because they may eventually return to their once-inhabited towns, we included them in the NRCA. We assessed the condition of black-tailed prairie dogs using one indicator/measure—area occupied and density of prairie dogs. We used both measures because we had limited data on each. Primary information sources for the assessment were a 2006 rare vertebrate species inventory conducted by the Colorado Natural Heritage Program (Sovell et al. 2008), the Historic Site's prairie dog management plan and environmental assessment (Sovell 2008), and a study on the prairie dog populations at the Historic Site (Pigg and Cully 2010). Our assessment looked at changes in the area occupied/density of prairie dogs over time. These measures were estimated for both prairie dog colonies in some years from 2001-2009. The north colony occupied 9.88 acres in 2009, but occupied 0 acres in 2010. The south colony occupied 153.20 acres in 2009, but occupied 0 acres in 2010. The density of prairie dogs in the north colony decreased from 13.3 prairie dogs per acre (measured in 2006) to 0 in 2010. The density in the south colony decreased from 17.8 prairie dogs per acre in 2009 to 0 in 2010. In early 2010, the sylvatic plague decimated the colonies at the Historic Site, resulting in 100% mortality. No prairie dogs have been observed at the Historic Site since that time. From an ecological standpoint, the condition of the black-tailed prairie dog at Sand Creek Massacre NHS is of significant concern. The trend is unchanging at this time. Based on available information, the condition had deteriorated to its lowest point in 2010, when the population was reduced to zero. There has been no evidence of an increase to date. The prairie dog population, however, could increase in the future (although this is an area of high uncertainty).

Rare Vertebrates			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence/absence of rare vertebrate species		The presence of rare vertebrate species at the Historic Site is a starting point for monitoring, particularly related to habitat needs and management practices. Insufficient information exists at this time to warrant a condition rating other than unknown.

Resource Brief

Sand Creek Massacre NHS represents an oasis of shortgrass prairie habitat surrounded by agriculture. The combination of shortgrass prairie, sandsage shrubland, and riparian habitat with pools and moving water create valuable habitat for a wide variety of species. Numerous wildlife species have been documented to use this site, a number of them of conservation concern. Surveys were conducted for swift fox, Arkansas darter, and Texas horned lizard, among others. Although these species were not found, additional surveys may be warranted, since the habitat conditions appear to be favorable. National Park Service units provide many benefits, among them habitat and protection for species considered threatened, endangered, or of conservation concern. Documenting the presence of rare species represents a starting point for future monitoring.

Aquatic Invertebrates			
Indicators of Condition	Specific Measures	Condition Status/Trend	Rationale
Species Occurrence	Presence/absence		The presence of several uncommon aquatic insects at the Historic Site is interesting, however, no additional information has been gathered to provide additional context for its occurrence. Insufficient information exists at this time to warrant a condition rating other than unknown.

Resource Brief

The documentation of aquatic insects is incomplete. A recent survey at Sand Creek Massacre NHS found two species uncommon to Colorado. The Black-fronted Forktail, a damselfly, is common to western marshes and springs and is uncommon in Colorado. The Bleached Skimmer, a dragonfly, is a localized species of eastern Colorado and regionally uncommon; it was commonly found at the Historic Site. This dragonfly was ranked, according to the Colorado Natural Heritage Program, as globally vulnerable and critically imperiled at the state level because of rarity.

5.3. Noteworthy Resource Condition Highlights

The list below provides examples of noteworthy highlights that will help to maintain or improve the condition of the Historic Site's natural resources.

Landscape Level Resources

Viewshed

- Although, there has been some development in and around the Historic Site, it remains relatively inconspicuous and the viewshed remains largely intact.
- The viewshed facilitates reflective contemplation of the historic sense of place.

Night Sky

- The night sky at the Historic Site is consistent with what is expected in a relatively remote rural setting.

Soundscape

- Sometimes during both winter day and night, sound levels were lower than what an average human ear could detect.

Vegetation Resources

Grasslands

- Most of the interior grasslands have no exotic plants detected.
- All measures of soil stability and hydrologic function indicate that conditions were good and even improving.
- Virtually all indicators of grassland condition were consistent with what might be expected given the historic disturbances of the site.

Exotics

- No exotic plants were found in more than half (57%) of park-wide exotic plants monitoring plots! In addition, all Historic Site staff participate in monitoring for new plant introductions and/or establishments, which promotes the rapid response necessary in controlling exotic plants.

Riparian Habitat

- All measures of hydrology, vegetation, and erosion/deposition indicate that riparian habitat conditions throughout the entire length of Big Sandy Creek were good.

Wildlife Resources

Landbirds

- A total of 72 bird species have been reported to occur at the Historic Site, with 50 of the species detected during 2009-2012 surveys. Twenty-five percent of the 72 species (or 18 species, excluding one non-native species) are considered species of conservation concern. Seven of these 18 species have high conservation potential at the Historic Site, because they are within their normal breeding ranges and breeding habitat exists for them at the Historic Site.

Rare Invertebrates

- The identification of rare species or species of conservation concern at Sand Creek Massacre NHS is noteworthy. Several factors make the Historic Site favorable habitat to the rare species mentioned, including the periodic presence of water in an arid landscape and an intact shortgrass prairie and sage shrubland that provides necessary habitat.

Aquatic Invertebrates

- A recent aquatic insects survey at Sand Creek Massacre NHS found two species uncommon to Colorado. The Black-fronted Forktail, a damselfly, is common to western marshes and springs and is uncommon in Colorado. The Bleached Skimmer, a dragonfly, is a localized species of eastern Colorado and regionally uncommon; it was commonly found at the Historic Site. This dragonfly was ranked, according to the Colorado Natural Heritage Program, as globally vulnerable and critically imperiled at the state level because of rarity.

5.4. Key Issues and Challenges for Consideration in Management Planning

Sand Creek Massacre NHS continues to contribute to the successful preservation of natural resources that are representative of the Southern Plains shortgrass prairie ecosystem of North America. In collaboration with its many partnerships, the Historic Site continues working towards understanding, monitoring, and preserving these important resources. This section provides some interpretations of some key issues and challenges identified throughout the development of this NRCA are discussed below.

Landscape Level Resources

Because most of the landscape level resources are greatly influenced by developments outside the Historic Site's boundary, preservation of these resources will require cooperation with surrounding landowners as well as local and regional governments. The potential future development of wind farms and/or oil and gas developments poses a risk to the quality of the viewshed because of the relative heights of these types of developments. These developments could potentially impact the night sky and soundscape resources as well. Currently, outdoor lighting on farm and ranch buildings near the Historic Site has the most potential to impair the quality of night sky viewing while noise from commercial jets flying to and from Denver International Airport is posing the most impact to the Historic Site's soundscape.

Supporting Environment Resources

In large part, there are several data gaps for the supporting environment resources, which include geology, surface water, air quality, and groundwater. Air quality is the exception since values can be extrapolated from other air quality monitoring locations. Unfortunately, the air quality values warrant a moderate air quality condition at the Historic Site, but on-site monitoring of ozone-sensitive plants may augment park-based knowledge of the extent of impact, if any. Conducting baseline inventories for the remainder of these resources as well as implementing a water quality program will greatly expand the knowledge of the Historic Site's supporting resources.

Vegetation Resources

This site was viewed as one that is nearly within its historical range of variability in terms of vegetation composition. The relatively low-abundance of nonnative plant species do not appear to be a threat to the site. The absence of prairie dogs due to recent plague may be a concern to some. However, as these animals now have the potential to greatly transform vegetation landscapes (Beals 2012, Seastedt et al. 2013), their absence assists managers in maintaining the native status of the grasslands.

The extent of woody vegetation (e.g. sagebrush) encroachment on grasslands will need to be considered in the context of desired future conditions. The historical data suggest that low to modest densities of this species should be the target goal for most areas (Seastedt et al. 2013). The trajectory of recovery from disturbance (e.g., CRP lands) is likely to be slow requiring decades or longer. Given the potential for invasion by exotic plants in an otherwise exotic-free environment at the Historic Site, the role of fire as a management tool will need to be carefully considered. For example, using fire as a tool to manage woody tree or shrub invasion may introduce a previously nonexistent problem such as the spread of cheatgrass.

Unlike most of the other park sites throughout the Southern Plains, the entire Historic Site is currently in good condition, and focus should be on maintaining that good condition versus fixing potential problems that may inadvertently arise through other management actions.

Wildlife Resources

The Burrowing Owl is considered a species of conservation concern by several agencies/organizations. The species has not been detected during Rocky Mountain Bird Observatory surveys at the Historic Site since 2009, when it was observed on a transect

in one of the prairie dog colonies. The owl prefers low grass structure and burrows, such as those provided by prairie dogs. Sovell et al. (2008) reported observing 18 Burrowing Owls during surveys in 2006. No Burrowing Owls have been observed at the Historic Site since around the time that the black-tailed prairie dog population crashed due to the sylvatic plague (in early 2010). The occurrence of species that rely on habitat created or influenced by the prairie dog may be affected by its absence. Although the loss of black-tailed prairie dogs at the Historic Site is of significant concern from an ecological standpoint, it is also recognized that the species causes management difficulties due to adjacent landowner concerns and the damage that prairie dog burrowing can cause to important cultural resources. It is uncertain as to whether or when prairie dogs will recolonize the Historic Site

The identification of rare species or species of conservation concern at Sand Creek Massacre NHS is noteworthy, and further study and monitoring is warranted to track habitat conditions associated with rare species occurrence. Unfortunately, because there have been limited studies, we lack a greater context in which to evaluate the two rare or uncommon aquatic insect species found at Sand Creek Massacre NHS . Since the Bleached Skimmer dragonfly is relatively abundant at the Historic Site, and critically imperiled at the state level, it seems like further study and monitoring is warranted to track the species and determine why the habitat conditions at the site are favorable, and if there is indication of a trend in habitat condition associated with its occurrence.

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Appendix A: Team Members and Subject Matter Experts

Table A.1. Sand Creek Massacre National Historic Site NRCA Project Team Members

Sand Creek Massacre NHS NRCA Project Team
Jeff Albright, NPS Water Resources Division's Coordinator of the NRCA Series
Alexa Roberts, NPS High Plains Group (Sand Creek Massacre, Bent's Old Fort and Capulin Volcano) Superintendent
Rob Bennetts, NPS Southern Plains Inventory and Monitoring Network Program Manager
Nina Chambers, Northern Rockies Conservation Cooperative, Writer/Editor
Tomye Folts-Zettner, NPS Southern Plains Inventory and Monitoring Network Biologist
Fran Pannebaker, NPS, Bent's Old Fort NHS, Chief Natural Resources
Heidi Sosinski, NPS Southern Plains Inventory and Monitoring Network Data Manager
Kim Struthers, Utah State University, Writer/Editor
Patty Valentine-Darby, University of West Florida, Biologist and Writer/Editor
Karl Zimmermann, NPS Sand Creek Massacre NHS, Chief Resources and Operations
Danette Ulloa, NPS Bent's Old Fort NHS Natural Resources Program Manager Assistant

Table A.2. Sand Creek Massacre NHS NRCA Subject Matter Experts

Subject Matter Expert	Topic	Project Deliverables
Jeff Albright, National Park Service Water Resources Division, Natural Resource Condition Assessment Series Coordinator	All	Program Level Review
Melanie Myers, Colorado State University GIS Analayst	Viewshed	Viewshed analyses
Chad Moore, National Park Service Night Sky Program Manager	Night Sky	Provided NPS guidance on night sky monitoring and review of night sky section
Emma Lynch, National Park Service Natural Sounds Program Acoustical Resource Specialist	Soundscape	Provided clarification of Sand Creek Massacre's soundscape 2011 report and provided graphs
Ellen Porter, National Park Service Air Resources Division	Air Quality	Reviewed air quality section
Bruce Heise, National Park Service Geologic Resources Division Geologist and Program Administrator, Geologic Resources Inventory	Geology	Reviewed geology section
Jason Kenworthy, National Park Service Geologic Resources Division Geologist	Geology	Reviewed geology section
Pete Biggam, National Park Service Geologic Resources Division Soil Scientist	Grasslands/Soils	Visited Sand Creek Massacre NHS as part of a rapid assessment team and the parts of this assessment related soil/site stability and hydrologic function are based on Biggam's assessment.
Mike Martin, National Park Service Water Resources Division, Hydrologist	Riparian Habitat	Provided expert opinion on riparian habitat during May 2012 field visit, submitted report, and reviewed riparian habitat boiler plate text used in Sand Creek Massacre's assessment via Little Bighorn Battlefield NM NRCA.
Joel Wagner, National Park Service Water Resources Division, Wetlands Program Leader	Riparian Habitat	Provided expert opinion on riparian habitat during May 2012 field visit

Table A.2. **Sand Creek Massacre NHS *NRCA Subject Matter Experts (cont.)***

Subject Matter Expert	Topic	Project Deliverables
Kevin Noon, National Park Service Water Resources Division, Wetlands Specialist	Riparian Habitat	Provided expert opinion on riparian habitat during May 2012 field visit
Alan Knapp, Colorado State University Department of Biology Professor	Grasslands	Provided expert opinion about grasslands during May 2012 field visit
Tim Seastedt, University of Colorado, Department of Ecology and Evolutionary Biology Professor	Grasslands	Provided expert opinion about grasslands during May 2012 field visit
Richard Gatewood, National Park Service Southwest Texas, Permian & Southern Plains Fire Groups, Fire Ecologist	Grasslands/Riparian Habitat	Reviewed grasslands and riparian habitat sections
Ross Lock Rocky Mountain Bird Observatory Wildlife Biologist	Landbirds	Ross provided expertise and information in development of the chapters, reviewed the approach taken in Capulin Volcano NM's NRCA landbird analyses
Chris White, Rocky Mountain Bird Observatory Wildlife Biologist	Landbirds	Assembled regional landbird information, provided consultation of landbirds section
Authors Who Served as Subject Matter Experts	**Topic**	**Project Deliverables**
Tomye Folts-Zettner National Park Service Southern Plains Inventory and Monitoring Network Biologist/ Botanist	All	Provided expert opinion on grasslands, exotic and riparian habitat plants. Reviewed entire NRCA
Heidi Sosinski, National Park Service Southern Plains Inventory and Monitoring Network Data Manager	Viewshed	Viewshed analyses

Appendix B: Viewshed Analysis Steps

The process Melanie Myers and Heidi Sosinski used to complete the Sand Creek Massacre NHP's viewshed analyses is listed below.

Downloaded spatial data from Internet.

Downloaded 1/3 arc second national elevation dataset (NED) grid (roughly equivalent to a 30 m digital elevation model [DEM]) from The National Map Seamless Server (http://seamless.usgs.gov/). The x and y values for the NED are in arc seconds while the z data are in meters. Projected NED into NAD83 UTM 13 to get all data in meters.

Downloaded Sand Creek Massacre National Historic Site boundary, roads, and trails layers from NPS Integrated Resource Management Applications (IRMA) portal (https://irma.nps.gov).

Prepared Observation Point layers for Viewshed Analyses.

Created point layers for entrance and upper parking lot.

Used Edit > Create New Feature tool to create 2 observation points (Bluffs Trail Overlook and Memorial Overlook). Saved file as obs_point.shp

Added field named "OFFSETA" (type = double) to shapefile and set value to 1.68 for each record in the attribute table. The value of 1.68 in the field "OFFSETA" represents an observer height of 1.68m (~5'6").

Initial analysis showed that using the default observer value in OFFSETA underestimated the visible area when compared to actual visibility on site. To account for this, an additonal offset of 10m was added to all analysis.

Added field named "OFFSETB (type = double) and set the value to 10. The value of 10 in the field "OFFSETB" represents the addtional 10 meters needed to reflect actual visibility.

Ran Viewshed Analysis using ESRI Spatial Analyst Viewshed Tool.

Using the Viewshed Tool in ESRI's ArcGIS 10, Spatial Analyst Toolbox, ran viewsheds using the following inputs.

Input raster = 1/3 arc second NED.

Input point observer feature = obs_point.shp.

Additional viewshed analysis were conducted to account for oil/gas and windfarm activity in the vicinity. Each new value incorporates the same 10m correction used in the initial analysis. The value of "OFFSETB" was adjusted to 53 (43m for the height of an average oil rig) 90 (80m for the height of a wind turbine) or 128.5 (118m for the height of a wind turbine including blades).

After the viewshed analyses were complete, housing and road density data were obtained and modified to depict past, present, and future densities around the Historic Site. These datasets were created by the NPS's Natural Resource Program Center by compiling and analyzing landscape-scale US Census Bureau data that linked measurable attributes of landscape (i.e., road density, population and housing density, etc.) to resources within natural resource based parks. This resulted in the creation of a dataset titled NPScape (Budde et al. 2009; Gross et al. 2009). The following modifications were made to NPScape data for purposes of this assessment:

Downloaded spatial data from Internet.

Downloaded Historic Site-specific NPScape data from the NPScape website (http://science.nature.nps.gov/im/monitor/npscape/index.cfm).

Simplified NPScape Housing Density Projections.

Table B.1. The original classes from NPScape and new classes assigned to housing densities for this assessment of the viewshed at Sand Creek Massacre NHP

Original Class	New Class
Private undeveloped	Private undeveloped
<1.5 units/square km	<1.5 units/square km
1.5–3 units/square km	1.5–6 units/square km
4–6 units/square km	
7–12 units/square km	> 6 units / square km
13–24 units/square km	
25–49 units/square km	
50–145 units/square km	
146–494 units/square km	
495–1234 units/square km	
Commercial / Industrial	Commercial / Industrial

Converted Sand Creek Massacre NHP 30 km housing density projection rasters to polygon shape files.

Combined classes to reduce number of original classes to five (Table B.1).

Appendix C: Bortle Dark-Sky Scale

Key for the Summer Sky— Latitudes 30° to 50° N

The Milky Way is not visible and sky glow extends above 35 degrees. Little to no dark adaptation is possible. Ground texture is easily seen, and artificial light dominates the landscape. Visible constellations are limited to the very brightest if any. The sky has a uniform washed out appearance.[1]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

Sky appears nearly completely washed out, and is luminous. Dark adaptation is not possible, ground is brightly illuminated and fewer than 200 stars are visible. Only the most major constellations are identifiable. For instance, the entire keystone of Hercules or the five stars of Delphinus are not completely visible.

this is accurate **Bortle Class 9** if darker—proceed below

Constellations are visible but may be missing key stars, sky background has a uniform washed out glow with light domes reaching 60 degrees above the horizon. Stars such as the tip of Sagitta or epsilon Lyrae are not visible. If clouds are present they are brilliantly lit.

this is accurate **Bortle Class 8** if darker—proceed below

Brighter constellations are easily seen in full, yet sky background has greyish or yellow background. Milky Way may be just barely seen near the zenith. The Scutum and Cygnus star clouds are not visible.If clouds are present they are brilliantly lit. Ground texture is still visible.

this is accurate **Bortle Class 7**

The Milky Way is visible but discontinuous, and lost to light domes near the horizon. Fine details and structure are not easily visible, if at all. Ground texture is still visible, and shadows are cast from light pollution. Light domes are clearly visible along the horizon and appear brighter than any portion of the visible Milky Way.[2]

If this describes your nighttime environment, continue below

If the nighttime environment appears darker than this description, jump to the next section

The Milky Way is just visible overhead, but is not continuous and is diminished to obvious skyglow. Cygnus ,Scutum, and Sagittarius star fields just visible. If clouds present they are illuminated and reflecting light. Ground texture is seen with difficulty.

this is accurate **Bortle Class 6** if darker—proceed below

Milky Way is faintly present, but may have occasional gaps and is lost to skyglow near the horizon. Great rift in Cygnus is just visible. Any clouds present are brighter than the background sky and reflect light back. Zodiacal light may be glimpsed, but is difficult to see amidst the light pollution. Ground texture is not visible but forms are easily seen.

this is accurate **Bortle Class 5** if darker—proceed below

Milky Way is evident from horizon to horizon, but fine details are lost. Clouds are just brighter than background sky, but appear dark at zenith. Light domes are much brighter than brightest part of Milky Way and extend to up to 15 degrees above the horizon. Zodiacal light is evident in west after sunset or in east before dawn. Deep sky objects such as the M13 globular cluster and Northern Coal Sac are visible.

this is accurate **Bortle Class 4**

The Milky Way has a defined outline with visible structure and detail. Very few light domes are visible just along the horizon and do not cast shadows. You may see color in the Zodical light when compared to bluish-white color of the Milky Way. Scattered clouds appear dark against the night sky except those clouds just above light domes.[3]

If this describes your nighttime environment, continue below

Milky Way appears complex with visible outline, however some light pollution is still evident along the horizon. Light domes only slightly brighter than brightest part of the Milky Way. Zodiacal light easily seen, but band and gegenschein difficult or absent. Many summer globular clusters and emission nebulae are visible with the naked eye despite distracting light domes along the horizon. Venus casts an obvious shadow.

this is accurate **Bortle Class 3** if darker—proceed below

Very few light domes are visible; with none extending above 5 degrees and fainter than the Milky Way. Airglow is often visible, and character in its brightness may be seen. Ground is mostly dark. The Zodiacal band (away from the Milky Way and at least 45 degrees above the horizon) and gegenschein are visible. The rift in the Cygnus star cloud is visible. The Prancing Horse in Sagittarius and Fingers of Ophiuchus dark nebulae are visible, extending to Antares. Jupiter and Milky Way cast barely visible shadows.

this is accurate **Bortle Class 2** if darker—proceed below

The Milky Way is intricate, marbled, and veined with Sagittarius region of the Milky Way casting obvious shadows. Milky Way appears 40 degrees wide in some parts with a convoluted outline. The horizon completely free of light domes, though some distant light domes may be visible from mountain tops. Transparency and seeing are excellent (among the best of the year) with very low airglow. Many objects such as M81 or the Helix nebula are visible with the naked eye. Zodical light is striking as a complete band. Any clouds are very difficult to see.

this is accurate **Bortle Class 1**

The Bortle Dark-Sky Scale is a qualitative scale developed by John Bortle and published in Sky & Telescope Magaine in 2001. It provides a useful complement to quantitative measures. The National Park Service is testing this dichotomous key for use by professional and citizen scientists. Some knowledge of the night sky and visual observational techniques are required to properly implement this assessment.

note 1) At least 5 minutes of dark adaptation is required to properly differentiate Class 7,8 & 9 skies.

note 2) At least 10 minutes of dark adaptation is required to properly differentiate Class 4, 5 & 6 skies.

note 3) 20 to 120 minutes of dark adaptation is required to properly differentiate Class 1, 2 & 3 skies.

Developed by Jeremy White, Dan Duriscoe, and Chad Moore of the NPS Natural Sounds & Night Skies Division, www.nature.nps.gov/night

August 2, 2012

Appendix D: Executive Summary - Rapid Soil Assessment

D.1. Overview

Sand Creek Massacre National Historic Site is located in Kiowa County, Colorado, in an area significantly impacted by accelerated wind erosion on arid croplands as part of the Dust Bowl in the 1930's. Additional impacts to the soil resources have occurred since then thru a variety of agricultural practices such as mechanical cultivation, irrigation, and livestock grazing. Since the park was established, these agricultural practices have been discontinued on most of the lands that the NPS administers within the park. Other more recent stressors to the soil resources was a prairie dog town in the southeast corner of the park which resulted in a severe denudation of herbaceous cover, and a dramatic increase in bare ground, highly susceptible to wind and water erosion. A recent plague epidemic has eliminated the prairie dogs, and the herbaceous cover has increased to a degree in which the soil resources are much better protected from erosion. The park staff has also implemented several resource management treatments that have benefitted the soil resources. One in particular has been the brush management treatment in which a small area of the park was mechanically mowed, which decreased the sand sage canopy, increased the herbaceous cover, and decreased the amount of bare ground, reducing the potential for soil erosion.

D.2. Procedure

The rapid soil assessments consisted of evaluating eight selected sites on the lands that the NPS currently manages. Areas within the park that are still under private ownership were not assessed. Locations of these sites can be found in Attachment 1 – Soil/Site Evaluation Locations.

The methodology used for these assessments followed an approach modified from those described in the qualitative assessment protocol "Interpreting Indicators of Rangeland Health (Version 4.0) (http://usda-ars.nmsu.edu/monit_assess/index.html), in which Soil/Site Stability qualitative indicators were used to assess the ability of an area to limit redistribution and loss of soil resources by wind and water.

Qualitative indicators can provide land managers and technical assistance specialists with a good communication tool, and when used in association with quantitative monitoring and inventory information, they can be used to provide early warnings of resource problems on upland rangelands.

These indicators were used in conjunction with soil survey information and ecological site descriptions for the eight selected evaluation areas, each of which were approximately 1/3 acre in size. It is important to note that only the Soil/Site Stability qualitative indicators were observed and documented on site, and these were what were used to perform the rapid soil assessments. The rapid soil assessment was used to determine the departure from the expected soil/site stability attributes.

Table D.2-1 lists the qualitative assessment indicators used to determine current soil/site attributes.

Table D.2-1. Qualitative assessment indicators used to determine current soil/site attributes.

Attribute	Qualitative Assessment Indicator
Soil/ Site Stability	Rills
	Water flow patterns
	Pedestals and/or terracettes
	Bare ground
	Gullies
	Wind-scoured, blowout, and/or depositional areas
	Litter movement
	Soil surface resistance to erosion
	Soil surface loss or degradation
	Compaction layer

Table D.2-2. Rapid soil assessment sites at Sand Creek Massacre NHS.

Site Number	Site Name	Soil Map Unit Symbol	Soil Series Documented at the Site	Ecological Site Documented at the Site	Soil Assessment and Departure from Expected Conditions
1	Big Head Site	37	Valent	Deep Sand (R069XY019CO)	None to Slight
2	Access Road Area	7	Valent	Deep Sand (R069XY019CO)	Slight to Moderate
3	Stabilized Blow out with slick spots	17	Keyner	Sandy Salt Flat (R069XY032CO)	None to Slight
4	Ditch Borrow Area	5	Glenberg	Sandy Bottomland (R069XY031CO)	Slight to Moderate
5	Range Mowing Site 1	5	Bankard	Sandy Bottomland (R069XY031CO)	None to Slight
6	Range Mowing Site 2	5	Glenberg	Sandy Bottomland (R069XY031CO)	None to Slight
7	Prairie Dog Town	21	Stoneham	Loamy Plains (R069XY006CO)	None to Slight
8	Eroded Drainage Bank	21	Kim	Loamy Plains (R069XY006CO)	Slight to Moderate*

* The assessment was a composite of the "Moderate to Severe" departure documented within the active gully, and the "None to Slight" departure in the upland areas within the total assessment area, resulting in a "Slight to Moderate" departure for the entire site.

Table D.2-2 depicts the seven sites evaluated, the informal site name, the soil map unit it occurs in, the soil component documented at the site, the ecological site documented at the site, and the soil assessment and departure from expected conditions.

Overall "Scorecard" of the Soil Resources of Sand Creek Massacre National Historic Site.



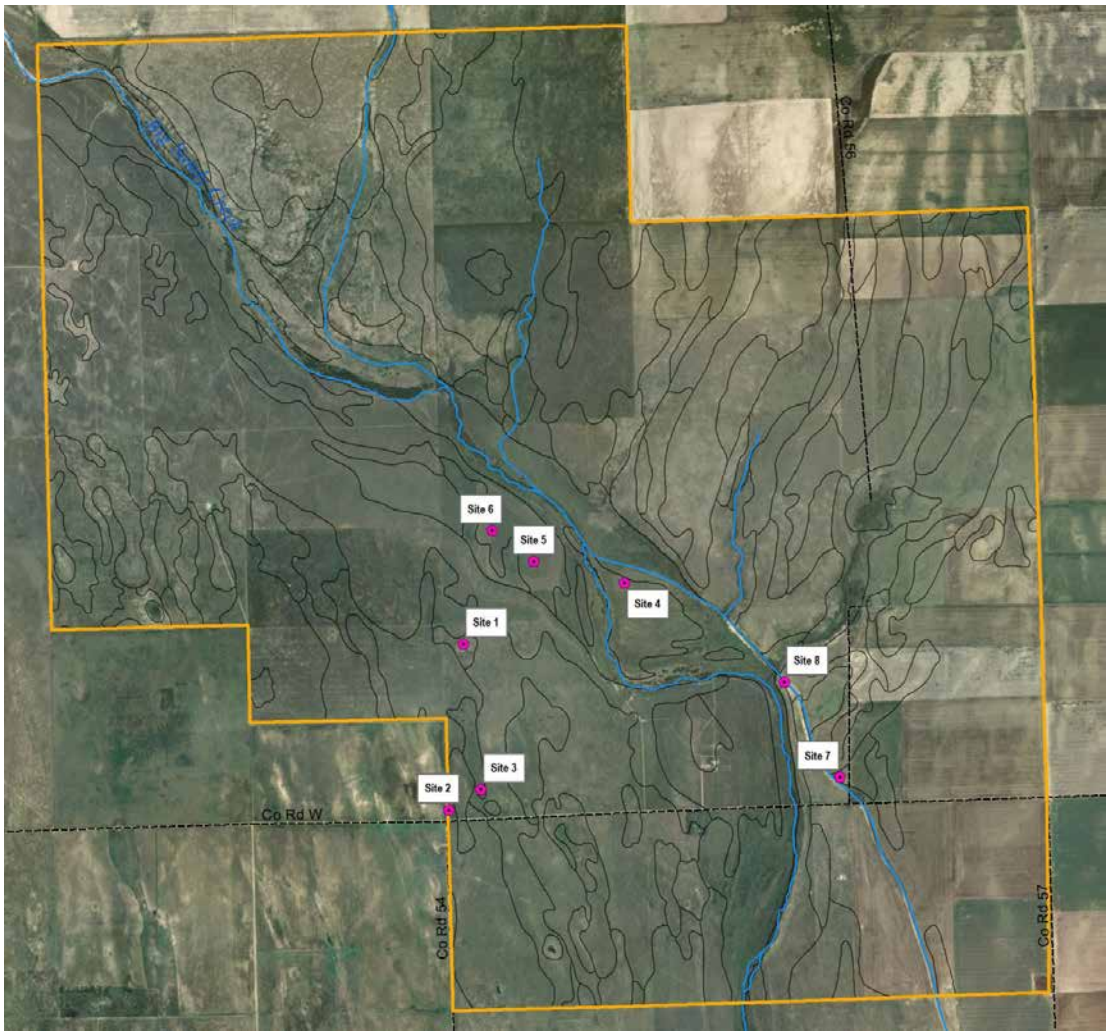


Figure D-1.
Soil/Site Evaluation Locations

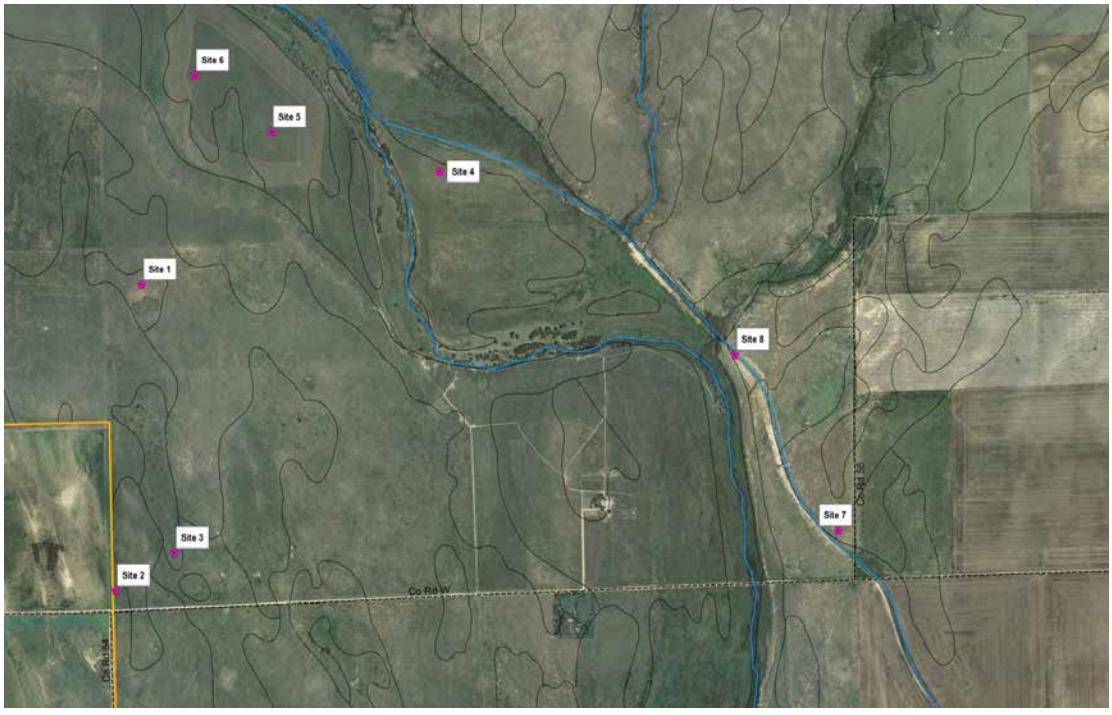


Figure D-2.
Site Locations within Sand Creek Massacre National Historic Site (Close-up view)

Appendix E: Handbook for Ranking Exotic Plants for Management and Control

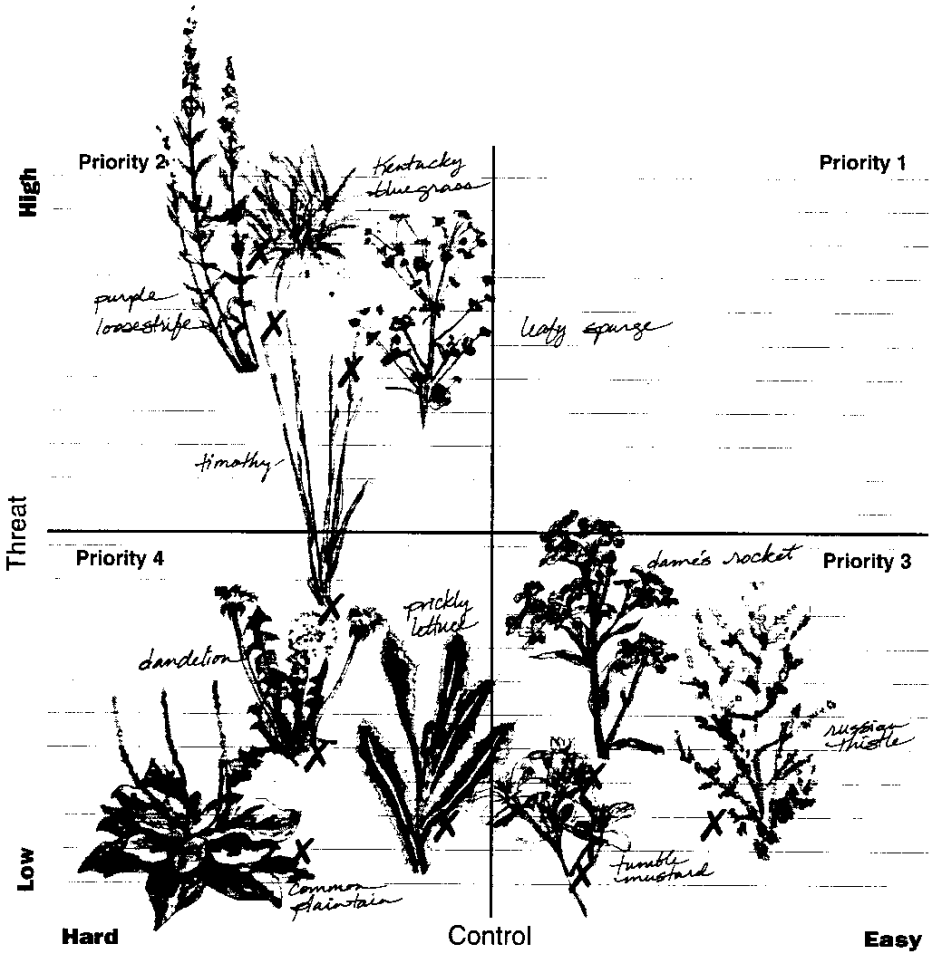
Handbook for Ranking Exotic Plants for Management and Control

Ronald D. Hiebert

and

James Stubbendieck

Natural Resources Report NPS/NRMWRO/NRR-93/08



United States Department of the Interior • National Park Service • Midwest Regional Office

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Handbook for Ranking Exotic Plants for Management and Control

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Introduction

Exotic, alien, introduced, nonindigenous, and nonnative are all synonyms for species that humans intentionally or unintentionally introduced into an area outside of a species' natural range. The National Park Service (NPS) defines exotic species as those occurring in a given place as a result of direct or indirect, deliberate, or accidental actions of humans. Thus, species native to the North American continent if outside their normal range due to the actions of humans are considered exotics by the National Park Service. The reader is directed to the *Natural Resources Management Guideline* (U.S. Department of the Interior, National Park Service 1991, NPS-77) to further clarify the definition.

Most exotic plant species cause minor effects on natural ecosystems. For example, Great Smoky Mountains National Park has approximately 1,500 vascular plant species, 400 of which are exotics--10 species are considered to be threatening to park resources. Of the 1,400 vascular plants at Indiana Dunes National Lakeshore, 300 are exotics, 14 of which are considered to be major threats. However, some exotic species can be extremely disruptive, such as disrupting the accurate presentation of a historic scene, damaging historic or archeological resources, interfering with natural processes, and threatening the survival of naturally evolved plant assemblages and individual native species.

Exotic species are often major roadblocks to managing natural resources in parks and other natural areas. Managing exotic plants is an extremely expensive, labor-intensive, and almost always a long-term proposition. Managers must not only be concerned with the level of impact that an exotic can cause but must also consider the impact of removing the species. Removal can often disturb areas that are easily colonized by the same or other exotic species (Westman 1990). The intensity and longevity of a control program are also important factors to consider in managing exotic plants. Therefore, managers must make sound decisions on where to place one's effort.

NPS policies, as they relate to managing natural resources, require that managers implement programs to maintain, restore, and perpetuate fundamental ecological processes as well as individual species and features. Managers are directed to manage not only for individual species but to maintain all the components and processes of naturally evolving park ecosystems (U.S. Department of the Interior, National Park Service 1988). Specific NPS

policy on exotic species directs park managers to give high priority to controlling and managing exotic species that have substantial impacts on park resources and that are believed to be easily managed. High priority should also be given to managing and monitoring exotic plant species that presently may not cause major impacts to park resources but have life history characteristics associated with colonizing or weedy species (Baker 1965) or are known to cause major impacts in other natural areas. Low priority should be given to species that cause little impact, are virtually impossible to control, or both.

A ranking system has been developed for resource managers to sort exotic plants within a park according to the species level of impact and its innate ability to become a pest. This information can then be weighed against the perceived feasibility or ease of control. The Exotic Species Ranking System is designed to first separate the innocuous species from the disruptive species. The separation allows researchers to then concentrate further efforts on species in the disruptive category. The system is also designed to identify those species that are not presently a serious threat but have the potential to become a threat and, thus, should be monitored closely. Finally, the system asks the park manager and the ecologist to consider the cost of delaying any action.

This handbook describes the rationale of the ranking system and its components and how to adapt the system to different situations and different areas of the country. The handbook also describes the information that is needed to apply the system, what the user should know, and how to use the system. Examples of products are given, along with suggestions of their application to management.

2

An Exotic Plant Ranking System

Why Use an Analytical Approach?

Several sound reasons exist for using an analytical approach as the basis of prioritizing exotic species. One of the basic reasons for using a decision analysis process is to get scientists involved in the decision-making process. Using a consistent and logical decision-making process prevents a biologist from compromising scientific excellence by becoming involved in environmental decisions based on incomplete information. Selecting an action alternative is similar to selecting a hypothesis. The action becomes an experimental manipulation to test the validity of the "hypothesis." A decision analysis process not only adds validity to a decision, but this process often demonstrates that inaction due to lack of complete information can have serious consequences (Maguire 1991).

If an analytical approach was not employed, decisions would most likely be based on the opinion of an individual or a group of individuals or decisions would be based on precedent. Granted, many field ecologists have a good idea of which exotic species are impacting natural ecosystem processes or impacting species composition. However, decisions based on judgment alone are rarely based on defined criteria, do not usually document the reasoning process, and give no assurance that the full array of significant factors were considered. Such decisions may suffer from personal biases and political whims. Decisions are hard to defend if challenged, and proposals for funding are hard to justify. Decisions based on precedent may be easier to defend but are not responsive to the variation in exotic species or natural system interactions over space and time. Thus, priorities set for managing exotic species based on precedent may not reflect current ecological and economic realities.

On the other hand, consistently using an analytical toot such as the Exotic Species Ranking System, can ensure that ecological knowledge is applied to the decision process and can remedy some of the problems associated with decisions based on judgment and precedent alone. An analytical framework encourages researchers to consider the full range of factors and consequences of their decisions. An analytical framework documents the procedures and the reasons for the decisions made, thus reducing the risk aversion characteristic of park managers. Decisions are defendable. Solid justification for program authorization and funding is at hand.

Origin

An earlier version of the system presented here was developed by Ron Hiebert. The system was modeled after a ranking system that was developed at Point Reyes National Seashore (Self 1986). The purpose of this system was to rank the effects of exotic species on the natural recovery of former residential sites at Indiana Dunes National Lakeshore. Hiebert (1990) observed that some exotic species were found only in severely and recently disturbed areas and seemed to have little effect on the succession process. Other exotic species were persistent but did not reproduce or spread, while others were persistent and had high rates of reproduction. Populations of some exotics were expanding within disturbed areas, while others were observed to invade surrounding undisturbed sites. Some of the most invasive and disruptive species were those with life history characteristics (high seed output, long-distance dispersal adaptations, ability to reproduce vegetatively) consistent with those related to weediness (Baker 1965). The present system was developed to support general NPS and park-specific policy, giving high priority to species causing major impacts (and are easily controlled) and giving low priority to species causing little impact (and extremely difficult to control).

Also, the system is designed to identify species that are currently rare and causing little impact but have a high potential to become a problem in the future.

The ranking system presented in this handbook has since been applied to ranking the exotic plants of Indiana Dunes (Klick et al. 1989) and six small national park system areas dominated by prairies and savannahs (Stubbendieck et al. 1992). As part of the latter, 14 plant ecologists reviewed the system. The system was modified to rank exotic plants in Olympic National Park (Olson et al. 1991) and was modified and used to rank both exotic plants and animals in the state of Minnesota (Minnesota Department of Natural Resources 1991). The system has been revised based on the above experiences and recommendations of users and expert reviewers.

Rationale For Use

The ranking system provides an ecologist or resource management specialist with a tool to sort exotic plant species based on their present level of impact and their innate ability to become a pest. Based on conscientious consideration of all the factors in the system, a person with good taxonomic and ecological skills should be able to separate those species that are innocuous from those that are disruptive or have a high potential to become disruptive. The resulting species rank can then be weighed against the ease or feasibility of control, and the urgency of action or the cost of delay in action can be determined.

For example, purple loosestrife *(Lythrum salicaria)* is ranked as the most disruptive exotic plant at Indiana Dunes National Lakeshore. Extensive efforts to eradicate or control its spread have not been successful. However, due to the significance of the impact, the National Park Service is funding research on its basic biology and on experimental control methods. In contrast, Scotch pine *(Pinus sylvestris)*is found to rarely reproduce and to cause only minor impacts throughout most of the park. Significant impacts are limited to one small prairie opening. Control is relatively simple--saw the pine down. Therefore, the park decided to eradicate Scotch pine from the prairie opening and to monitor its status in other park locations.

An example of the urgency ranking as applied is European alder *(Alnus glutinosa)*. This species was found at or in close proximity to one razed residential site at Indiana Dunes National Lakeshore. However, the species had spread into a large, dense clone of thousands of ramets in just six years and was also reproducing sexually. The species was reported to be highly invasive and to cause major impacts in other natural areas. Therefore, the National Park Service considered quick action to be prudent.

In summary, the ranking system encourages resource managers to logically apply criteria that address the present impact of a species on ecological

processes and structure and on other park resources. The ranking system also predicts the potential of a species to become a pest in the future. Normally, applying the system will greatly reduce the list of exotic species with which a park manager needs to be concerned. The decision to take management action against a species determined to be disruptive then can be weighed on the basis of the level of impact, the feasibility of successful control, and the prediction of the cost of delay in action. The information accumulated in the system's application serves as solid documentation to support management's decisions and to justify program funding

Description

The Exotic Species Ranking System in Table 1 uses numerical ratings, is written in outline format, and is divided into two main sections: I. Significance of Impact and II. Feasibility of Control or Management. Each section is based on a scale of 100 points.

Table 1. Exotic Species Ranking System (Ronald D. Hiebert)

I.	Significance of Impact	
A.	Current Level of Impact	
1.	Distribution relative to disturbance regime	
a.	found only within sites disturbed within the last 3 years of sites regularly disturbed	-10
b.	found in sites disturbed within the last 10 years	1
c.	found in midsuccessional sites disturbed 11-50 years before present (BP)	2
d.	found in late-successional sites disturbed 51-100 years BP	5
e.	found in high-quality natural areas with no known major disturbance for 100 years	10
2.	Abundance	
a.	number of populations (stands)	
(1)	few; scattered (<5)	1
(2)	intermediate number; patchy (6-10)	3
(3)	several; widespread and dense (>10)	5
b.	areal extent of populations	
(1)	<5 ha	
(2)	5-10 ha	2
(3)	11-50 ha	3
(4)	>50 ha	5
3.	Effect on natural processes and character	
a.	plant species having little or no effect	0
b.	delays establishment of native species in disturbed sites up to 10 years	3
c.	long-term (more than 10 years) modification or retardation of succession	7
d.	invades and modifies existing native communities	10
e.	invades and replaces native communities	15
4.	Significance of threat to park resources	
a.	threat to secondary resources negligible	0
b.	threat to areas' secondary (successional) resources	2
c.	endangerment to areas' secondary (successional) resources	4
d.	threat to areas' primary resources	8
e.	endangerment to areas' primary resources	10

Table 1 (cont).

5. Level of visual impact to an ecologist	
a. little or no visual impact on landscape	0
b. minor visual impact on natural landscape	2
c. significant visual impact on natural landscape	4
d. major visual impact on natural landscape	5
Total Possible = 50	
B. Innate Ability of Species to Become a Pest	
1. Ability to complete reproductive cycle in area of concern	
a. not observed to complete reproductive cycle	0
b. observed to complete reproductive cycle	5
2. Mode of reproduction	
a. reproduces almost entirely by vegetative means	1
b. reproduces only by seeds	3
c. reproduces vegetatively and by seed	5
3. Vegetative reproduction	
a. no vegetative reproduction	0
b. vegetative reproduction rate maintains population	1
c. vegetative reproduction rate results in moderate increase in population size	3
d. vegetative reproduction rate results in rapid increase in population size	5
4. Frequency of sexual reproduction for mature plant	
a. almost never reproduces sexually in area	0
b. once every five or more years	1
c. every other year	3
d. one or more times a year	5
5. Number of seeds per plant	
a. few (0-10)	1
b. moderate (11-1,000)	3
c. many-seeded (>1,000)	5
6. Dispersal ability	
a. little potential for long-distance dispersal	0
b. great potential for long-distance dispersal	5
7. Germination requirements	
a. requires open soil and disturbance to germinate	0
b. can germinate in vegetated areas but in a narrow range or in special conditions	3
c. can germinate in existing vegetation in a wide range of conditions	5
8. Competitive ability	
a. poor competitor for limiting factors	0
b. moderately competitive for limiting factors	3
c. highly competitive for limiting factors	5
9. Known level of impact in natural areas	
a. not known to cause impacts in any other natural area	0
b. known to cause impacts in natural areas, but in other habitats and different climate zones	1
c. known to cause low impact in natural areas in similar habitats and climate zones	3
d. known to cause moderate impact in natural areas in similar habitats and climate zones	5
e. known to cause high impact in natural areas in similar habitats and climate zones	10
Total Possible = 50	

6

Table 1 (cont).

II. Feasibility of Control or Management	
A. Abundance Within Park	
1. Number of populations (stands)	
a. several; widespread and dense	1
b. intermediate number; patchy	3
c. few; scattered	5
2. Areal extent of populations	
a. > 50	1
b. 11-50 ha	2
c. 5-10	3
d. < 5ha	5
B. Ease of Control	
1. Seed banks	
a. seeds remain viable in the soil for at least 3 years	0
b. seeds remain viable in the soil for 2-3 years	5
c. seeds viable in the soil for 1 year or less	15
2. Vegetative regeneration	
a. any plant part is a viable propagule	0
b. sprouts from roots or stumps	5
c. no resprouting following removal of aboveground growth	10
3. Level of effort required	
a. repeated chemical or mechanical control measures required	1
b. one or two chemical or mechanical treatments required	5
c. can be controlled with one chemical treatment	10
d. effective control can be achieved with mechanical treatment	15
4. Abundance and proximity of propagules near park	
a. many sources of propagules near park	0
b. few sources of propagules near park, but these are readily dispersed	5
c. few sources of propagules near park, but these are not readily dispersed	10
d. no sources of propagules are in dose proximity	15
C. Side Effects of Chemical/Mechanical Control Measures	
1. control measures will cause major impacts to community	0
2. control measures will cause moderate impacts to community	5
3. control measures will have little or no impact on community	15
D. Effectiveness of Community Management	
1. the following options are not effective	0
2. cultural techniques (burning, flooding) can be used to control target species	5
3. routine management of community or restoration or preservation practices (e.g., prescribed burning, flooding, controlled disturbance) effectively controls target species	10
E. Biological Control	
1. biological control not feasible (not practical possible, or probable)	0
2. potential may exist for biological control	5
3. biological control feasible	10
Total Possible = 100	

Urgency	
1. Delay in action will result in large increase in effort required for successful control.	High
2. Delay in action will result in moderate increase in effort required for successful control.	Medium
3. Delay in action will result in little increase in effort required for successful control.	Low

I. Significance of Impact is further divided into A. Current Level of Impact and B. Innate Ability of Species to Become a Pest. Stubbendieck et al. (1992) considered a species with a combined score of over 50 points for significance of impact to be seriously disruptive and needing appropriate attention. Species receiving high scores for feasibility of control will be easier to control than those receiving lower scores. A step-by-step description of the system follows.

I. Significance of Impact

A. Current Level of Impact: This section concentrates on ranking the species based on the present degree and extent of impact caused by the exotic species. Element 1 addresses where the species is found along a disturbance regime. If the species is found in only sites that are recently or frequently disturbed, the species is not considered a serious threat. If the species is found in mature undisturbed natural communities, the species is considered a serious threat. Element 2 addresses how many populations (stands) are found in the park and the size of the populations. Element 3 rates a species based on its effects on the ecological processes and structure of native communities. Element 4 addresses which park resources are threatened. Finally, element 5 addresses the visual impact as seen by an ecologist.

B. Innate Ability of Species to Become a Pest: This section ranks a species based on the life history traits that preadapt it to become a problem and its known impacts in other areas. Important life history characteristics include potential rate of increase, adaptations for long-distance dispersal, and the breadth of habitats in which the species can colonize and thrive. Element 1 is essentially a screening device. If the species cannot reproduce in the area, the species most likely will not pose much of a threat. Likely species that will not reproduce in an area are horticultural species transferred from areas with different environmental conditions. Element 2 addresses how a species reproduces. The assumption is that vegetative reproduction allows an adapted ecotype to be maintained, resulting in local spread. Sexual reproduction allows for the maintenance of genetic variation and propagules for long-distance dispersal and the possibility of forming highly adapted gene combinations. If the species can reproduce both vegetatively and sexually, that species has the best of both worlds.

Elements 3, 4, and 5 address the factors that determine the intrinsic rate of increase of a species--how many seeds are produced how often. Element 6 deals with the species ability to disperse. This factor can usually be rated based on the presence or absence of special adaptations for seed or fruit dispersal, such as wings and pappi for wind dispersal, bladders for water dispersal, or bristles for animal dispersal. Element 7 asks if the species needs bare soil (disturbed) to germinate or if the species can germinate in a relatively closed (undisturbed) community. Element 8 looks at what the species can do once the species has colonized an area. Is the species able to outcompete native species for light, water, etc.? Finally, scientists should not ignore what the effects of the species have been in other natural areas.

8

II. Feasibility of Control or Management

Less is known about the feasibility of managing exotic plants in natural areas than what impacts they have on the natural systems. Most research efforts in controlling plants have been in agriculture where the goal is to control all but one species while not harming the single-crop species. In natural areas, the goal is to control one or a few species while not harming diverse assemblages of native species. However, many factors will affect the funds and effort required for control and the probability of success.

A. Abundance Within Park: No explanation is needed here. The larger the populations and the larger the number of populations, the larger the funds and effort required to manage the species.

B. Ease of Control: This section not only deals with life history characteristics that impact the level of effort that will be needed to control the species, but also the probability of success if unlimited funds and personnel are used. Element 1 addresses the seed bank which directly influences the needed duration of a control program. Information on the longevity of viable seeds in soil is not available for many species, therefore making this element hard to score. However, a best estimate should be made based on the information that is available. Element 2 addresses the vegetative reproduction of the species, which influences the number and kinds of treatments required to control the species, whether the underground parts of the plant must be removed, and also dictates the protocol for disposal of plant material. Element 3 not only addresses the level of effort required, but also the kind(s) of control measures required. Element 3 follows the preferred steps of the NPS Integrated Pest Management Program in that mechanical treatment is preferred over chemical treatment. Element 4 deals with the presence or absence of propagules adjacent to the park and the probability of propagules being dispersed into the park. Consideration should be given to the park's ability to control the species outside its boundaries through cooperative control programs.

C. Side Effects of Chemical/Mechanical Control Measures: As stated earlier, researchers must consider what effects eradication or control measures will have on the system being restored or preserved. Will the treatment open up areas for the same species to recolonize or be invaded by other equally or more impacting exotics? In some cases, the lesser of two unsatisfactory options may be not taking any action.

D. Effectiveness of Community Management: Controlling exotic species through sound management of the system based on ecological study is by far the preferred control method. In some cases, controlling trampling by visitors, restoring historical fire regimes, or restoring shoreline processes or natural hydrological regimes will shift the competitive edge to the desired native species.

E. Biological Control: Biological control is ecologically feasible for many exotic species. However, due to the high costs to develop well-tested biological control agents, it is only economically feasible for exotic species causing major impacts over a broad geographical area and normally only if the species are causing an economic impact as well as an ecological impact. Similarly, biological control is not feasible if the species to be controlled has some economic value. Abundance of closely related native species in the area where the exotic is to be controlled also lowers the feasibility because of possible negative side effects. The responsibility of conducting long-term studies involved with selecting and screening possible control agents lies with the U.S. Department of Agriculture.

Urgency: After the species are ranked according to their level of impact and feasibility of control or management, the exotic species that demands the most attention should be addressed first. The cost of delaying an action either financially or in impact to the natural resources of the park is a good criterion to use in making this often difficult decision.

How to Use the System

Work will be conducted both in the field and in the library. Individuals using the Exotic Species Ranking System must have training in biology because the system requires interpreting specific biological information on each species in the field as well as in the literature. A working knowledge of plant taxonomy is required to properly identify species in the field. Identification may be difficult for the less trained because some of the exotic species are members of genera containing native species as well, and proper separation may be made on relatively fine differences between plants.

The first step in using the Exotic Species Ranking System is to inventory the exotic plant species. Names of plant species should be assembled from (1) species lists and research reports for the park, (2) the catalog of specimens from the park herbarium, and (3) a preliminary field survey of the vegetation. Each species on the completed list should be checked in references, especially the flora for the area, to determine if a species is native or exotic.

The second step is to conduct an intensive survey of the park. The survey should include the location and extent of populations of each exotic species. The information obtained in this survey will be used to complete Current Level of Impact (I.A.), a portion of Innate Ability of Species to Become a Pest (I.B.), and Abundance within Park (II.A.) Usually, two surveys are required. One survey should be conducted in late spring when most cool-season species are flowering, and the second should be conducted in late summer to correspond with flowering of warm-season species. The extent and number of populations should be drawn on a map during the survey. The map will be important for managers to locate exotic species for continued monitoring and future control.

The third step is a comprehensive search of the literature for information on the ecology, biology, and control methods for each exotic species. Information from this part of the process will be used for a portion of Innate Ability of Species to Become a Pest (I.B.) and the majority of II. Feasibility of Control or Management. Computer data bases in most libraries simplify the search procedure. Key words for the search should include the scientific and common names for each species. Not all of the articles will be applicable, but the computer-generated titles and abstracts generally will indicate whether the complete article should be located. The most commonly used journals are listed in Appendix A. Making photocopies of the article for both the ranking process and to place in the files for future reference may be helpful. Unfortunately, the amount of information in the literature varies considerably with the species. For example, articles on common exotic species such as Kentucky bluegrass *(Poa pratensis)* are abundant. Many of the articles are related to turf and turf grass management and have essentially no value for the ranking process. Considerable time is required to separate articles with useful information from the available literature. On the other hand, the literature

contains few articles on less abundant exotic species. Occasionally, ranking an individual species may be difficult because not enough information can be located. For example, no reference may be available that contains few articles on less abundant exotic species. Occasionally, ranking an individual species may addresses the length of time seeds remain viable in the soil. The person ranking the species may then need to investigate seed bank ecology of other species within the genus or make a decision based on seed morphology.

An additional source of information may be the element stewardship abstracts prepared by The Nature Conservancy. These comprehensive abstracts are available for some of the common species.

The next step of the process is to complete the Exotic Species Ranking System Data Summary Form (see Appendix B for a blank form) for each species by bringing together all of the information that has been gathered in the previous three steps. The person conducting the ranking should read each step of the Exotic Species Ranking System outline in Table 1 and, based on information gathered, select the appropriate numerical value That value is placed on the Data Summary Form.

An Example: Pipestone National Monument

Intensive exotic species surveys at Pipestone National Monument in Minnesota were conducted during 1989-91. Over 70 exotic species were located and ranked using the Exotic Species Ranking System (Table 2); 11 species were ranked as being highly disruptive (a total of 50 or more points for I. Significance of Impact). These results show that a relatively low proportion of the exotic species will be highly disruptive. None of the highly disruptive species was classified as being easy to control (Figure 1).

Of the 11 highly disruptive exotic species, feasibility of control of quackgrass *(Agropyron repens)* scored the least (16), while feasibility of control of white sweetclover *(Melilotus alba)* scored the greatest (48). Based on knowledge of the individual exotic species, control of only Canada thistle *(Cirsium arvense)* was considered to be urgent.

Canada Thistle

A Data Summary Form for Canada thistle at Pipestone National Monument is presented in Table 3. The data summary in Table 3 may be compared to the outline of the Exotic Species Ranking System in Table 1 to see how Canada thistle was evaluated for each step.

Species Abstract

An additional product that may be obtained from the Exotic Species Ranking System is an abstract for each important species. Generally, important species are those ranked as highly disruptive (a total of 50 or more points for I. Significance of Impact). An outline of the format for a species abstract may be found in Table 4. An example of a species abstract prepared for Canada thistle is in Appendix C.

Table 2. Ranking of exotic plant species (arranged alphabetically) at Pipestone National Monument.

	Significance of Impact				
Species	Current Level of Impact	Innate Ability to Become a Pest	Total	Feasibility of Control	Urgency
Agropyron cristatum	-8	27	19	56	Low
Agropyron repens	28	36	64	16	Medium
Agrostis stolonifera	7	25	32	41	Low
Asparagus officinalis	4	25	29	65	Low
Brassica kaber	-8	16	8	65	Low
Bromus inermis	42	43	85	18	Medium
Bromus japonicus	18	20	38	51	Low
Bromus tectorum	17	20	37	38	Low
Campanula rapunculoides	6	26	32	46	Low
Capsella bursa-pastoris	-2	17	15	37	Low
Carduus nutans	19	34	53	31	Medium
Chenopodium album	-5	18	13	56	Low
Cirsium arvense	19	40	59	17	High
Cornilla varia	12	32	44	34	Medium
Dianthus armeria	4	16	20	60	Low
Digitaria sanguinalis	13	24	37	36	Medium
Eleagnus angustifolia	17	30	47	30	Medium
Eragrostis cilianensis	-8	16	8	50	Low
Euphorbia esula	24	48	72	31	High
Hesperis matronalis	-4	19	15	63	Low
Kochia scoparia	-8	31	23	55	Low
Lactuca serriola	-4	17	13	49	Low
Lappula echinata	7	32	39	50	Low
Lappula redowskii	6	30	36	50	Low
Leonurus cardiacea	9	19	28	43	Low
Lepidium campestre	13	20	33	33	Low
Linaria vulgaris	18	29	47	41	Medium
Lithospermum arvense	4	23	27	65	Low
Lolium perenne	-8	19	11	50	Low
Lonicera tatarica	33	39	72	25	Medium
Matricaria matricariodes	-8	17	9	65	Low
Medicago lupulina	-5	24	19	41	Low
Medicago sativa	10	34	44	34	Low
Melilotus alba	17	34	51	48	Medium
Melilotus officianilis	14	34	48	42	Medium
Nepeta cataria	9	21	30	46	Low
Philadelphus coronarius	9	22	31	45	Low
Phleum pratense	10	30	40	36	Low

Table 2 (cont).

	Significance of Impact				
Species	**Current Level of Impact**	**Innate Ability to Become a Pest**	**Total**	**Feasibility of Control**	**Urgency**
Plantago major	-8	24	16	30	Low
Poa compressa	33	34	67	21	Medium
Poa palustris	18	20	38	51	Low
Poa pratensis	38	43	81	23	Medium
Polygonum achoreum	-8	22	14	60	Low
Polygonum aviculare	-4	22	18	46	Low
Polygonum hydropiper	3	30	33	30	Low
Polygonum persicaria	13	21	34	45	Low
Populus nigra	6	30	36	45	Low
Portulaca oleracea	10	24	34	31	Low
Potentilla fruticosa	6	25	31	60	Low
Potentilla recta	18	22	40	31	Low
Ranunculus testiculatus	-8	21	13	75	Low
Rhamnus cathartica	45	44	89	18	Medium
Rumex crispus	-6	27	21	35	Low
Salsola iberica	-6	31	25	75	Low
Setaria faberi	-8	26	18	55	Low
Setaria glauca	-8	29	21	55	Low
Setaria viridis	-2	26	24	38	Low
Silene cserei	-8	16	8	60	Low
Silene pratensis	-8	19	11	60	Low
Sisymbrium altissimum	-8	21	13	60	Low
Solanum dulcamara	-1	22	21	50	Low
Sonchus arvensis	20	39	59	22	Medium
Taraxacum officinale	-4	33	29	34	Low
Thalspi arvense	-8	18	10	55	Low
Tragopogon dubius	7	26	33	31	Low
Trifolium hybridum	-8	25	13	50	Low
Trifolium pratense	18	23	41	36	Low
Trifolium repens	11	29	40	36	Low
Ulmus pumila	18	29	47	36	Low
Verbascum thapsus	15	22	37	36	Medium
Veronica arvensis	6	19	25	55	Low

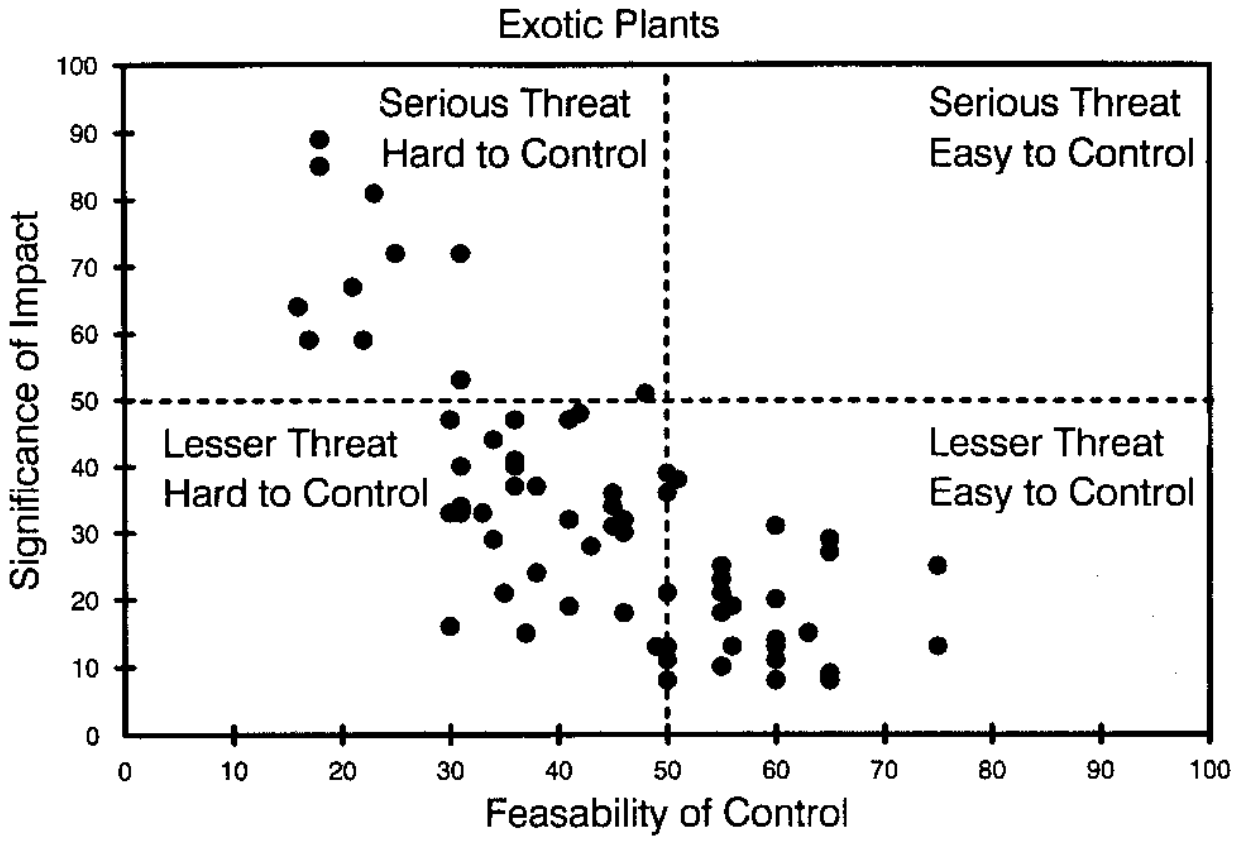


Figure 1. Plot of level of impact vs. feasibility of control for exotic plant species at Pipestone National Monument, Minnesota.

Adaptability

The system presented in this handbook was designed to rank exotic plants in parks and natural areas in the Midwestern states with medium-to-high productivity and fairly rapid successional rates. However, the system is designed to be adaptable for different biogeographical areas or groups of organisms, or to be applied at various scales. To adapt the system to different biogeographical areas, the time scale for disturbance regimes can be modified as appropriate. The system was adapted to rank plants and animals at a statewide scale by the state of Minnesota. This ranking was done by the Minnesota Department of Natural Resources. The Minnesota task force applied the system to plants and animals, including birds, mammals, fish, reptiles, amphibians, insects, mollusks, and crustaceans. Rather than use the methods presented here for a single park or natural area, the task force applied them on a statewide basis using averages per county for the abundances ratings.

Table 3. Completed Exotic Species Ranking Summary Form for Canada thistle *(Cirsium arvense)* at Pipestone National Monument.

Exotic Species Ranking System
Data Summary Form

Park: Pipestone National Monument Species: *Cirsium arvense*

Significance of Impact:

Current Level of Impact (50)	19		
Innate Ability to Become a Pest (50)	40	Total (100)	59
Feasibility of Control:		Total (100)	17
Urgency:			High

I. Significance of Impact:

A. Current Level of Impact

1.	Distribution relative to disturbance regime (-10, 1, 2, 5, 10)	2
2.	Abundance	
	a. number of populations (1, 3, 5)	3
	b. areal extent of populations (1, 2, 3, 5)	1
3.	Effect on natural processes and character (0, 3, 7,10, 15)	7
4.	Significance of threat to park resources (0, 2, 4, 8, 10)	4
5.	Level of visual impact to an ecologist (0, 2, 4, 5)	2
	Total (50 possible)	19

B. Innate Ability of Species to Become a Pest

1.	Ability to complete life cycle in area of concern (0, 5)	5
2.	Mode of reproduction (1, 3, 5)	5
3.	Vegetative reproduction (0, 1, 3, 5)	5
4.	Frequency of sexual reproduction (0, 1, 3, 5)	5
5.	Number of seeds per plant (1, 3, 5)	5
6.	Dispersal ability (0, 5)	5
7.	Germination requirements (0, 3, 5)	0
8.	Competitive ability (0, 3, 5)	5
9.	Known level of impact in natural areas (0, 1, 3, 5, 10)	5
	Total (50 possible)	40
	A + B (100 possible)	59

Table 3 (cont).

II.	Feasibility of Control or Management	
	A. Abundance Within Park	
	1. Number of populations (1, 3, 5)	3
	2. Areal extent of populations (1, 2, 3, 5)	3
	B. Ease of Control	
	1. Seed banks (0, 5, 15)	0
	2. Vegetative regeneration (0, 5, 15)	0
	3. Level of effort required (1, 5, 10, 15)	1
	4. Abundance and proximity of propagules (0, 5, 10, 15)	0
	C. Side Effects of Chemical/Mechanical Control (0, 5, 15)	5
	D. Effectiveness of Community Management (0, 5, 10)	0
	E. Biological Control (0, 5,10)	5
	Total (100 possible)	17
Urgency:		High

Table 4. Outline of a species abstract.

Park (full name and abbreviation)

Scientific Name (with authority)

Synonyms (if any)

Common Name(s)

Urgency Ranking

Overall Ranking

Significance of Impact
- A. Current impact
- B. Ability of species to become a pest

Feasibility of Control or Management

Taxonomic Description:
- A. Life form
- B. Height
- C. Vegetative characteristics
  - Stems
  - Underground (roots, rhizomes, etc.)
  - Leaves
    - arrangement
    - type
    - sheaths and ligules (of grasses)
    - size
    - margins
    - surfaces (pubescence)
    - attachment
    - petiole
- D. Floral characteristics
  - Inflorescence
    - type
    - size
  - Flowers of forbs and woody plants
    - type
    - size
    - bracts
    - calyx
    - corolla
    - color
    - anthers and ovary
  - Spikelets of grasses
    - florets
    - glumes
    - lemmas
    - paleas
    - awns

Table 4 (cont).

E. Fruit characteristics
   Type
   Shape
   Size
   Color
   Attachments for dispersal
F. Varieties (if any)

Biology and Ecology:

A. Origin
B. Habitat
C. Distribution (current and historical)
D. Climatic and ecological range
   Soils
   Disturbance
   Temperature
   Precipitation
   Soil moisture
   Light
   Fertility
   Other
E. Reproduction
   Type (asexual or sexual with flowering period)
   Ecological requirements
   Rate
   Seed production (including number per plant)
   Dispersal
   Longevity in seed bank
F. Germination

Distribution:

A. Number in the park
B. Size of populations
C. Location and successional sites
D. Relationship to disturbance
E. Invasion potential
F. Visual impact

Control:

A. Considerations
B. Mechanical
C. Cultural
D. Chemical
E. Biological

References:

Local Control Experts:

A. Extension weed control specialists
B. Department of Natural Resources
C. Other

Applying Results to Management Action

The logical species to give the highest priority are those that seriously threaten natural resources yet appear to be easy to control. The lowest priority should be given to those species that pose little threat and would be difficult to control. An easy way to categorize the ranked exotics is to plot the level of impact against the feasibility of control. Plots for Pipestone National Monument and Wilson's Creek National Battlefield are in Figures 1 and 2. As demonstrated in these two cases, the majority of the species are not considered to be a serious threat to park resources. This pattern is consistent with all surveys done to date. Also of note is that no species fall in the quadrant of serious threat and easy to control. We predict that this scenario will be the norm. Deciding which species or group of species in which areas need to be targeted for control is not easy. However, the resource manager now has only a few species to consider and should be equipped with most of the information available to guide a decision. The information will also aid in developing at least rough cost estimates and needed time commitments for various control scenarios. The resource manager also has the background information to defend a decision. The urgency ranking should also help indicate the resource and financial costs of delay in action.

The resource manager may determine that the most serious threat is uncontrollable on a parkwide basis. Control efforts may need to be restricted to rare communities or to areas where the exotic species threatens an endangered species. Control efforts may be futile within the park without cooperation from neighbors, as ample propagules for reinvasion exist near park boundaries. The only known successful control may require using an herbicide that has possible serious side effects. A decision to divert at least a portion of the effort towards investigating ways to shift the competitive advantage from the exotic to the native species or developing methods for easy and economic control of selected exotics may be appropriate. A decision often will require selecting the lesser of several evils. However, with diligence, by soundly applying information to management decisions, and documenting and communicating successful and unsuccessful control efforts, progress can be made in managing exotic species in natural areas.

Cautions

As with any tool, this system can be misused.

1. This ranking system provides a tool to resource managers and biologists who are knowledgeable of the area and species under investigation. They will benefit by using the system to consistently consider all of the important ecological and managerial elements for all exotic species. The ranking system provides the information in a format that can serve as a solid foundation on which to base an action plan. However, as is the case with most tools, the system can be misused or even be harmful if not used as intended or if not used by a skillful craftsman.

2. Separating the innocuous species from the disruptive species and consistently generating information on exotic species is the purpose of the system. The actual numeric values have little meaning or value.

3. The information provided by using this system to survey and rank exotic species is good for a specific place and time. Ecological systems are highly dynamic, and the distribution abundance and level and type of impact will change over time and space.

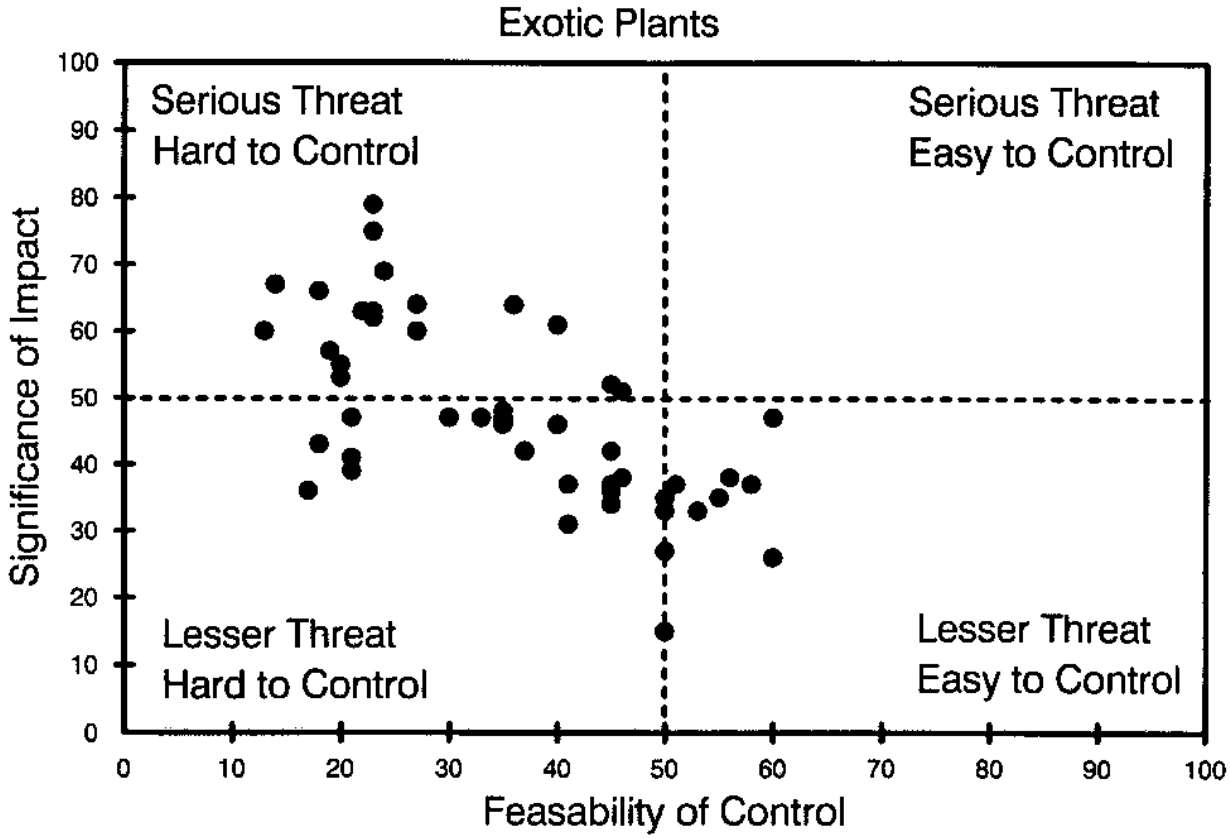


Figure 2. Plot of level of impact vs. feasibility of control for exotic plant species at Wilson's Creek National Battlefield, Missouri.

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U.S. Department of the Interior, National Park Service. 1988. Management Policies.

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Westman, W.E. 1990. Park management of exotic plant species: problems and issues. Conservation Biology 4:251-260.

Names of Journals of Commonly Used Sources of Information for Exotic Species

Journals

Acta Biotheroretica
African Journal of Ecology
Agronomy Journal
American Journal of Botany
American Midlands Naturalist
American Naturalist
Annual Review of Ecology & Systematics
Annuals of Botany
Biological Conservation
Botanical Gazette
Bulletin of the Torrey Botanical Club
Canadian Journal of Botany
Canadian Journal of Plant ScienceWeed Technology
Conservation Biology
Crop Science
Ecological Modelling
Ecology
Environmental Ecology
Environmental Management
Grass and Forage Science
Great Basin Naturalist
HortScience
Journal of Agricultural Economics
Journal of Applied Ecology
Journal of Arid Environments
Journal of Biogeography
Journal of Ecology
Journal of Economic Entomology
Journal of Entomological Science
Journal of Range Management
Journal of Vegetation Science
Natural Areas Journal
New Phytologist
Oecologia
Oikos
Paleobiology
Physiologia Planatarum
Phytopathology
Plant Disease
Plant Physiology
Quarterly Review of Biology

Journals

Rangelands
Restoration and Management Notes
SIDA
Soil Science
Soviet Journal of Ecology
Vegetatio
Weed Research
Weed Science
Weeds

Exotic Species Ranking System
Data Summary Form

Park: _____ Species: _____

Significance of Impact:

Current Level of Impact (50) ____

Innate Ability to Become a Pest (50) ____ Total (100) ____

Feasibility of Control: Total (100) ____

Urgency: ____

I. Significance of Impact.

A. Current Level of Impact

1. Distribution relative to disturbance regime (-10,1, 2, 5,10) ____
2. Abundance
   a. number of populations (1, 3, 5) ____
   b. areal extent of populations (1, 2, 3, 5) ____
3. Effect on natural processes and character (0, 3, 7, 10, 15) ____
4. Significance of threat to park resources (0, 2, 4, 8, 10) ____
5. Level of visual impact to an ecologist (0, 2, 4, 5) ____

Total (50 possible)

B. Innate Ability of Species to Become a Pest

1. Ability to complete life cycle in area of concern (0, 5) ____
2. Mode of reproduction (1, 3, 5) ____
3. Vegetative reproduction (0, 1, 3, 5) ____
4. Frequent of sexual reproduction (0, 1, 3, 5) ____
5. Number of seeds per plant (1, 3, 5) ____
6. Dispersal ability (0, 5) ____
7. Germination requirements (0, 3, 5) ____
8. Competitive ability (0, 3, 5) ____
9. Known level of impact in natural areas (0, 1, 3, 5, 10) ____

Total (50 possible) ____

A + B (100 possible) ____

II. Feasibility of Control or Management

A. Abundance Within Park

1. Number of populations (1, 3, 5) ____
2. Areal extent of populations (1, 2, 3, 5) ____

B. Ease of Control

1. Seed banks (0, 5, 15) ____
2. Vegetative regeneration (0, 5, 15) ____
3. Level of effort required (1, 5, 10, 15) ____
4. Abundance and proximity of propagules (0, 5, 10, 15) ____

C. Side Effects of Chemical/Mechanical Control (0, 5, 15) ____

D. Effectiveness of Community Management (0, 5, 10) ____

E. Biological Control (0, 5, 10) ____

Total (100 possible) ____

Urgency: ____

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Species Abstract of Canada Thistle at Pipestone National Monument, Minnesota

Park:	Pipestone National Monument
Species:	*Cirsium arvense* (L.) Scop.
Common Name:	Canada thistle, field thistle, creeping thistle, California thistle
Urgency Ranking:	High
Overall Ranking:	8
Significance of Impact:	59
A. Current impact:	19
B. Ability to become a pest:	40
Feasibility of Control or Management:	17

Taxonomic Description:

Canada thistle is a dioecious, perennial forb reaching heights of up to 1.5 m. This species's erect stem is highly branched above, green, and glabrescent-to-covered with dense cobweb-like hairs. Canada thistle usually occurs in small to large patches with numerous individuals arising from horizontal, lateral roots bearing adventitious shoots. Leaves are simple and placed alternately on the stem. Lower cauline leaves are 5-18 cm long and 1.5-6 cm wide, oblong to oblanceolate, and entirely or shallowly to pinnately lobed. Each lobe has few to many spines, and some spines are up to 5 mm in length. Both leaf surfaces may be glabrous, or the upper surface may be lightly pubescent while the lower surface is densely pubescent. Cauline leaves are reduced in size upwards and less lobed. Leaves may have a petiole up to 1 cm long, sessile, clasping, or short decurrent. Heads are numerous and occur in terminal corymb-like clusters. Each head is discoid and unisexual or incompletely dioecious. Pistillate flowers are 1-2 cm high and 0.5-1 cm wide, and staminate flowers are somewhat shorter. Bracts are imbricate, in five to six rows, ovate to lanceolate (2-6 mm long and up to 1.2 mm wide), spine-tipped with a spine up to 1 mm long, and glabrous to covered with a dense cobweb-like hair. The corolla is tubular and pink or purple in color (occasionally white). Staminate corolla tubes are 12-14 mm long, and anthers are 3.5-4 mm long and occasionally have vestigial pistillate parts. Pistillate corollas are longer (19-24 mm long) and may have vestigial anthers. Achenes are light brown to straw-colored (2-4 mm long and up to 1.5 mm wide). Each achene has a pappus of numerous white to grayish plumose bristles reaching up to 2.5 cm in length. Four varieties of this species have been recognized: var. *vestitum* Wimm. & Grab., var. *integrifolium* Wimm. & Grab., var. *arvense* (L.) Scop., and var. *horridum* Wimm. & Grab.

Biology and Ecology:

Canada thistle is a highly competitive and noxious weed. It was apparently introduced from Eurasia into North America in colonial times as a contaminate of agricultural seed. Now a naturalized weed, Canada thistle is most commonly found in agricultural lands, pastures, and rangelands. The weed has also become established in forests, riversides, roadsides, lawns, gardens, abandoned fields, and ditchbanks. Canada thistle can now be found in all of the lower 48 states and all of the Canadian provinces.

Canada thistle is most common in open, mesophytic areas. It has a temperature tolerance of -35º to 40º C. Optimal annual precipitation is 400-750 mm. The species grows in a wide variety of soils, including sand dunes, but is most abundant in clayey soils. It can tolerate saline soils and wet or dry soils, but grows best in dry soils. Disturbance is necessary for initial establishment; however, once established it may rapidly spread by both rhizomes and seed. Canada thistle is not generally shade tolerant. Its growth is reduced when light falls to 60-70% of full daylight, and death occurs when light is reduced to 20% of full sun. This tolerance level may explain why Canada thistle does not persist in prairies in good to excellent condition. The species also does not readily tolerate waterlogged, poorly aerated soils. However, it may be found growing in these conditions in a lowered condition.

Extensive rhizomes of Canada thistle make it unique among the thistles. Rhizomes develop at depths far below the zone of rhizome development for most species. Most rhizome development occurs in the first 75 cm of the soil, but has been reported to occur at nearly 7 m. Lateral root growth of up to 6 m in one growing season has been recorded. Root buds are produced on lateral roots at 6-12-cm intervals. With these closely placed buds, root fragments as small as 8 mm in length and 3-6 mm thick have produced new shoots, and root fragments 13 cm in length nearly always produce new shoots. Root fragments can produce viable shoots in as few as five days. Root/shoot elongation increases with temperature and photoperiod. Elongation is greatest at 25º/15º C day/night temperatures, soil temperatures of 30º C, and a photoperiod of 15 hours. Root reserves are lowest just before flowering and are the greatest in early fall when aboveground growth stops.

Shoots begin to emerge in the early spring when soil temperatures reach about 5º C. Development of rosette leaves occurs first followed by vertical elongation in early summer. Flowering is generally from June to September, when day length reaches 14 to 18 hours. Canada thistle is incompletely dioecious, with the staminate and pistillate flowers usually borne on separate plants. Therefore, natural patches are usually of one sex. Flowers are pollinated by insects, primarily honey bees and some wasps. Each plant produces from 30 to 100 heads in a season. Each pistillate head has about 100 fertile florets, and about 83 to 90 will form seeds. One plant has the potential to produce up to 5,200 seeds in a season, but the average seed production is about 1,530 seeds per plant. Seeds are dispersed primarily by wind. Seed size is variable, averaging 650,000 to nearly 1,500,000 per kg.

Germination rates of between 50% and 95% have been observed. An average of 90% of the yearly seed production germinates within one year. Studies have shown that some seeds can remain viable in the soil for up to 21 years and up to four months in water. Optimal germination in the laboratory occurs with temperatures at a constant 30º C or where temperatures alternate between 20º and 30º or 30º and 40º C. Germination is restricted with osmotic pressures above 5 bars. Optimal germination is between pH 5.8 and 7.0. Each crop of seed produces a succession of seedlings. Some will germinate that fall and produce a rosette. These will then flower the next summer. Other seeds will not germinate until the next spring (or later) and may or may not flower that year.

Some evidence indicates that Canada thistle may have an allelopathic effect; however, no specific compound has been isolated. Autotoxicity has been hypothesized in some circumstances.

Distribution:

An intermediate number of Canada thistle plants are present at Pipestone National Monument. They occur in patches and cover less than a total of 5 ha. Canada thistle plants are found in midsuccessional sites that were disturbed in the last 11 to 50 years. These plants have the potential to invade and modify existing native plant communities and may endanger the secondary successional resources. The plants have a minor visual impact on the park.

Control:

Numerous control options exist for Canada thistle. Biological, chemical, cultural, and mechanical methods have all been used with varying levels of success. An important consideration in controlling Canada thistle is that the seeds have the potential to remain viable in the seed bank for at least 20 years. Thus, removing living plants may not totally eliminate the problem. A further consideration is that many sources of new propagules surround the park.

An important consideration prior to applying any control method is to determine if enough desirable plants are present to replace the Canada thistle. If desirable vegetation is absent or not present in enough numbers, control will be of little value. Most control methods will have a detrimental effect on other plant species, and they all constitute a disturbance that will favor reinvasion by Canada thistle or by other exotic species. Researchers should note that many native thistles are present in the area, and they should not be subjected to control. Proper identification is important.

Frequent mowing over a number of years will control Canada thistle. Mowing has been the primary control method employed at Pipestone. Most studies indicate a need to mow patches of Canada thistle at least twice a year to prevent seed dispersal and reduce root reserves. Systematic monthly mowings may be necessary to prevent lateral flower bud development and to keep root reserves depleted. Tillage may be used to control Canada thistle; however, tillage may result in an increase in abundance due to spreading rootstalks and the subsequent disturbance. Tillage should be to a depth of 10 cm when the elongated shoots are 8 to 10 days old. Tillage should be repeated at a minimum of 21-day intervals. Canada thistle has a relatively high light requirement, and smother crops may provide some measure of control by shading. Smother plants that have been used include sweet clover, alfalfa, millet, sorghum, hemp, and small grains.

No prescribed burning studies have been conducted to specifically control Canada thistle. Supplementary information has shown that repeated burning in May or June reduced thistle abundance in grasslands. In most of these studies, Canada thistle showed an initial increase in abundance, followed by a notable reduction in abundance.

A number of chemical control options exist for Canada thistle. Many herbicides discussed here are not specific to Canada thistle or may not be specifically licensed for this particular type of use. Thus, users must read and follow all label directions. Before “modern” herbicides were introduced, compounds such as sodium chloride, sodium arsenite, calcium arsenite, sodium chlorate, and carbon bisulfide were all used in attempts to control Canada thistle. Numerous herbicides are now available for controlling Canada thistle. Tordon (pidoram) is probably the most effective. Tordon may give a 95% control in the first year when applied at a rate of 0.56-1.23 kg ai/ha in the spring before flowering or in the fall during active rosette growth. Banvel (dicamba) applied at 0.56-6.73 kg ai/ha or 2,4-D (amine) at 0.56 2.24 kg ai/ha will suppress or control Canada thistle. However, more effective control may be achieved by combining the two herbicides in a 1:1 mixture. This mixture should be applied in the spring before flowering or in the fall when the rosettes are actively growing. Roundup (glyphosate) applied at a rate of 1-2 kg ai/ha at the bud stage or during the active growth period in the fall will also control this thistle. Amitrole-T (amitrol) applied at rates of 2.24-4.48 kg

ai/ha when the plants are in the bud stage has yielded 70% control in the first year. Most herbicides, except Tordon, should not be applied while the plants are in a moisture-stressed condition. Other herbicides that have shown potential to control Canada thistle are Buctril 2EC (bromoxynil), Curtail (clopyralid plus 2,4-D), and Stinger (clopyralid).

Biological control of Canada thistle has received some attention. Over 80 native species of insects and over 50 species of animals and fungi use Canada thistle to some extent. A few species have the potential for providing same measure of control. Only four insects may be a threat to Canada thistle. These four are composed of two beetles [*Cassia rubiginosa* Muell. (Coleoptera: Chrysomelidae) and *Cleonus piger* (Coleoptera: Curculionidae)], one fly [*Orellia ruficauda* Fab. (Diptera: Tephritidae)], and the painted lady butterfly [*Vanessa cardui* L. (Lepidoptera: Nymphaidae)]. Only *Orellia ruficauda* appears to do significant damage to Canada thistle, and this level of damage is not sufficient for control. Five European insect species [*Ceutorhynchus litura* F. (Coleoptera: Curculionidae), *Rhinocyllus conicus* Froelich (Coleoptera: Curculionidae), *Altica carduorum* Guerin-Meneville (Coleoptera: Chrysomelidea), *Lema cyanella* L. (Coleoptera: Chrysomelidae), and *Urophora cardui* L. (Diptera: Tephritidae)] have all been released in North America for Canada thistle control. To date, only *Ceutorhynchus litura* has become established, spread, and begun to suppress this plant.

Fungus species of the genus *Puccinia* hold some promise as control agents. *Puccinia punctiformis* (Strauss) Roehling (Fungus: Uredinales) has been tested in Europe and New Zealand and has been found to only reduce plant vigor. The best biological control of Canada thistle has come when this fungus has been used in conjunction with either 2,4-D, or *Ceutorhynchus litura.* Plants treated with the fungus followed by weevil introduction had over a 50% increase in damage over nontreated plants.

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Notes





As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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Appendix F: Exotic Plant Species Listed But Not Currently Present

The following table lists exotic species that are not currently found within Sand Creek Massacre National Historic Site but have been previously listed in either reports or files.

Scientific Name	Common Name	Roath et al. 2008	SAND Plants Photos List 2008	SAND Plants List 6-08.xls	SAND_ WABA_ plants.xls	SOPN_ 2009_ SAND_ 09.xls	NPS 2011	Folts-Zettner et al. 2012	Folts-Zettner et al. 2013
Aster sp.	Several unknown species						●		
Astragalus spp.	Several unknown species						●		
Brassicaceae sp.	Unknown						●		
Carduus nutlans	Nodding musk thistle				●	●			
Carduus tenuiflorus	Italian thistle				●	●			
Chenopdium spp.	Several unidentified spp.						●		
Chloris verticillata	Tumble windmill grass			●					
Conyza canadensis	Bermuda grass			●				●	
Dipsacus fullonum spp. sylvestris	Common teasel					●			
Dracopis sp.	Unknown						●		
Eleocharis sp.	Spike rush						●		
Euphorbia esula	Leafy spurge			●					
Fabaceae sp.	Unknown						●		
Linum sp.	Unknown						●		
Oxytropis sp.	Unknown						●		
Panicum sp.	Unknown						●		
Solanum rostratum	Buffalo bur	●	●	●					
Verbena brasiliensis	Brazilian vervain				●				

Appendix G: Maps of the Known Distribution of Exotic Plant Species At Sand Creek Massacre NHS

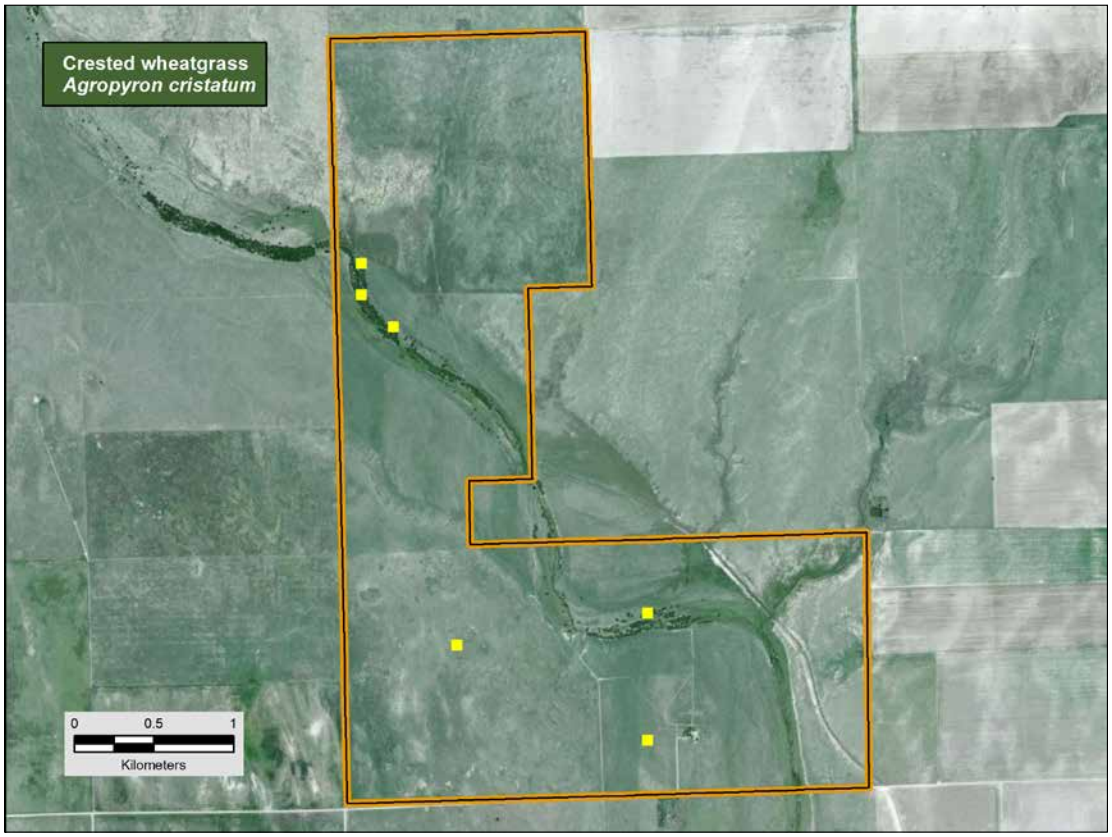


Figure G-1. Crested wheatgrass (*Agropyron cristatum*)

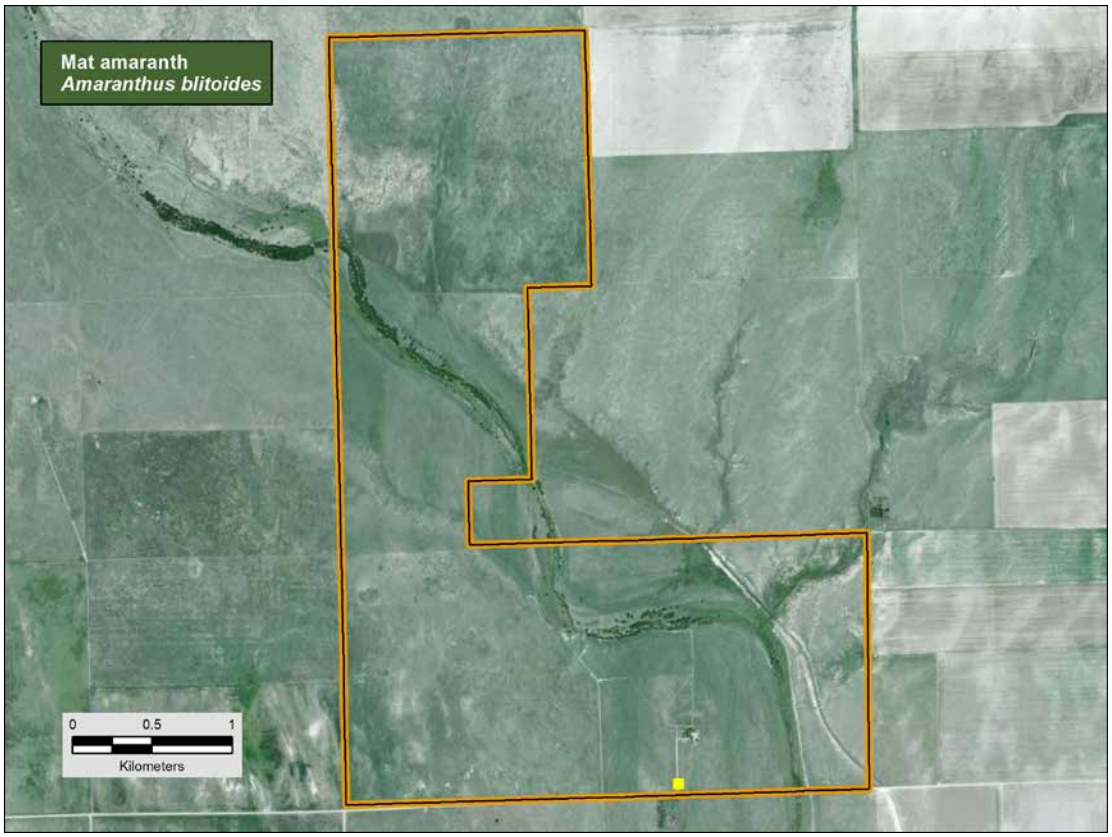


Figure G-2. Mat amaranth (*Amaranthus blitoides*)

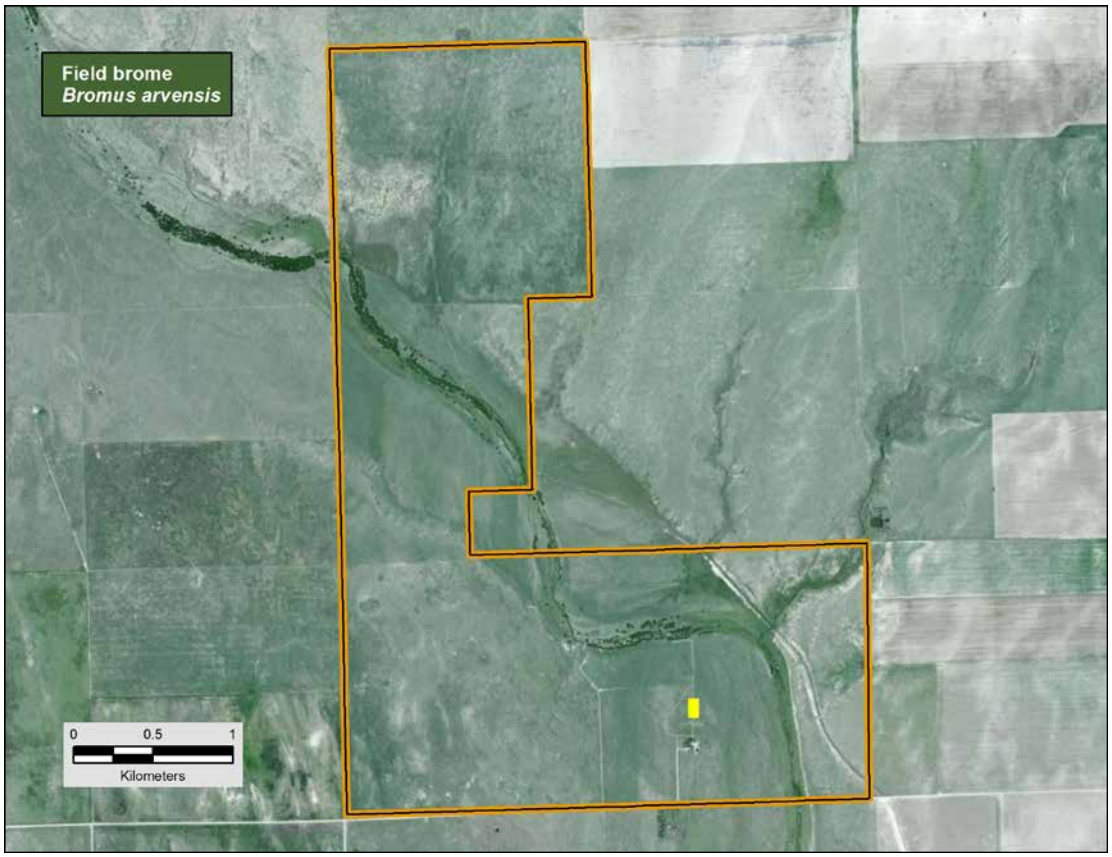


Figure G-3.
Field brome (*Bromus arvensis)*

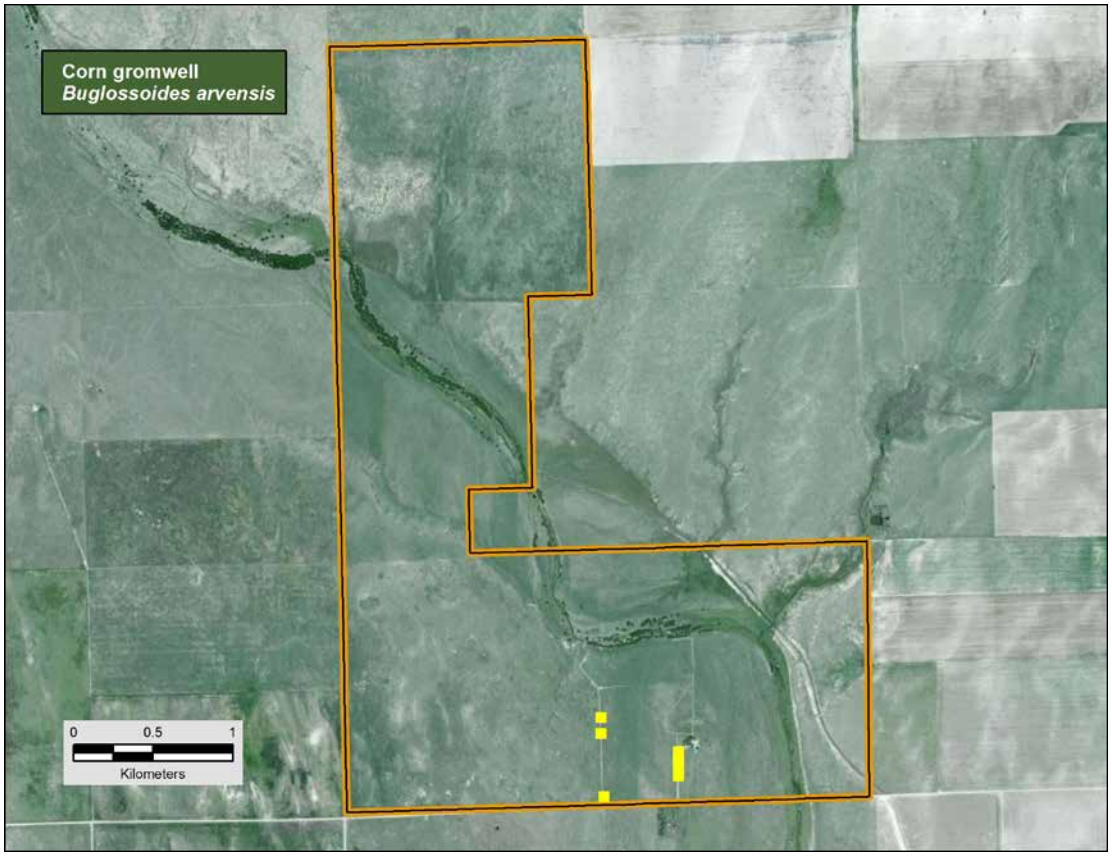


Figure G-4.
Corn gromwell (*Buglossoides arvensis)*

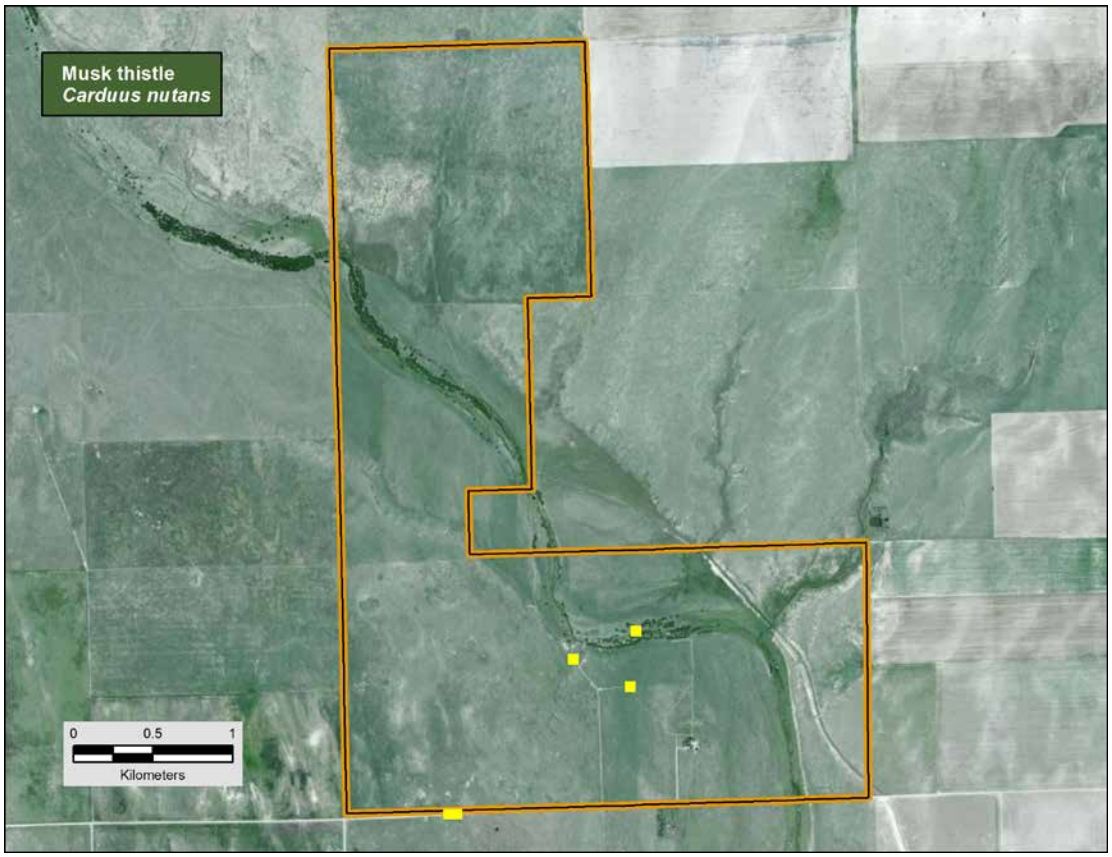


Figure G-5. Musk thistle (*Carduus nutans)*

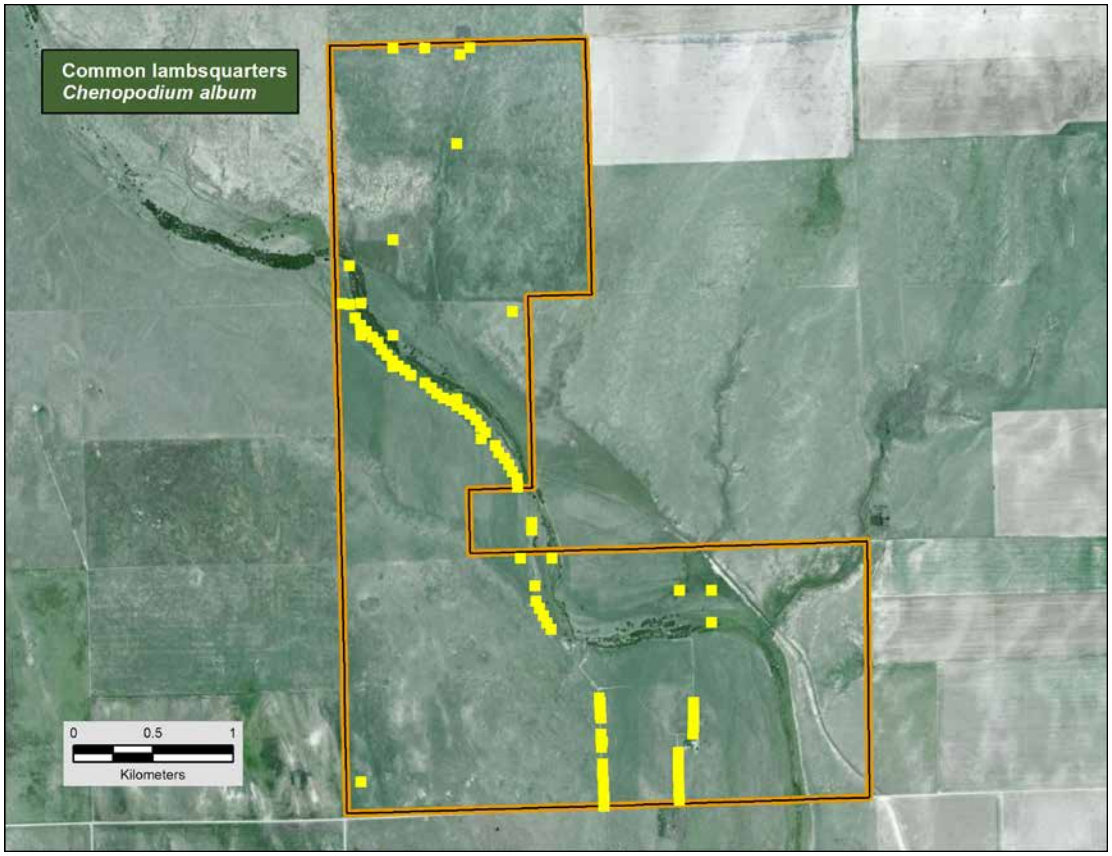


Figure G-6. Common lambsquarters (*Chenopodium album)*

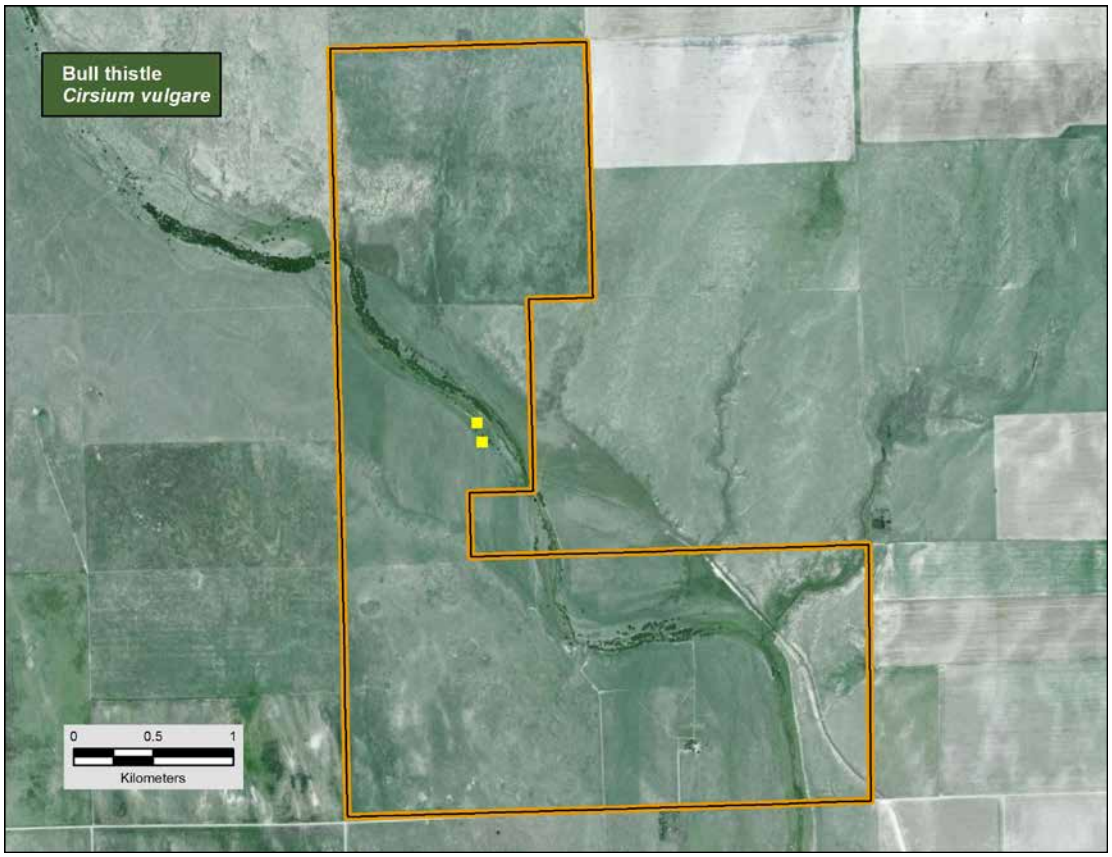


Figure G-7.
Bull thistle (*Cirsium vulgare)*

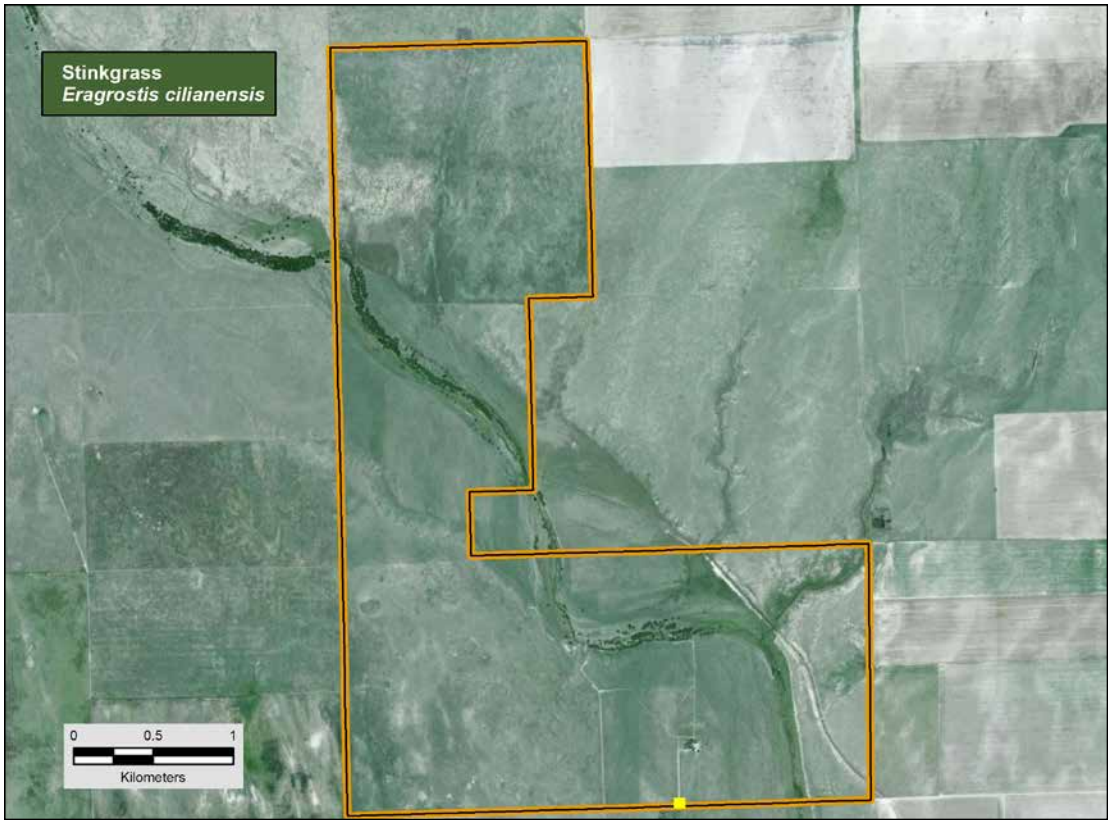


Figure G-8.
Stinkgrass (*Eragrostis cilianensis)*

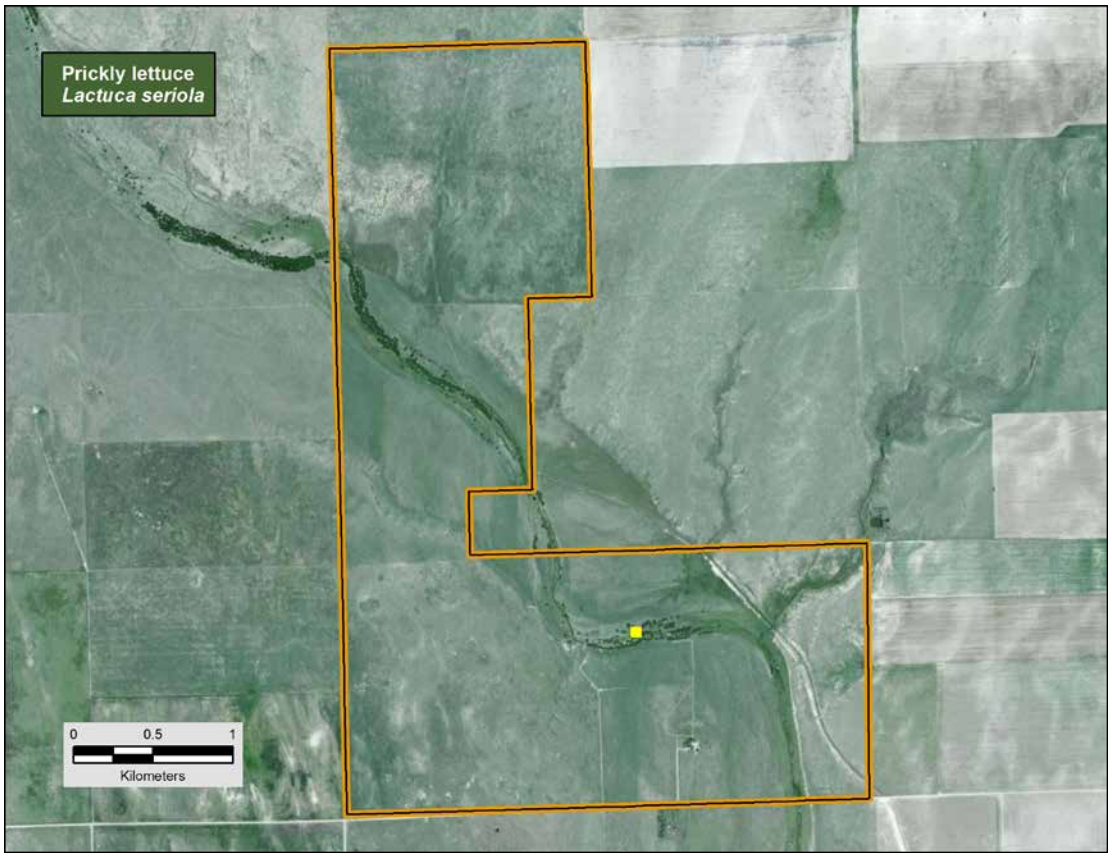


Figure G-9. Prickly lettuce (*Lactuca serriola)*

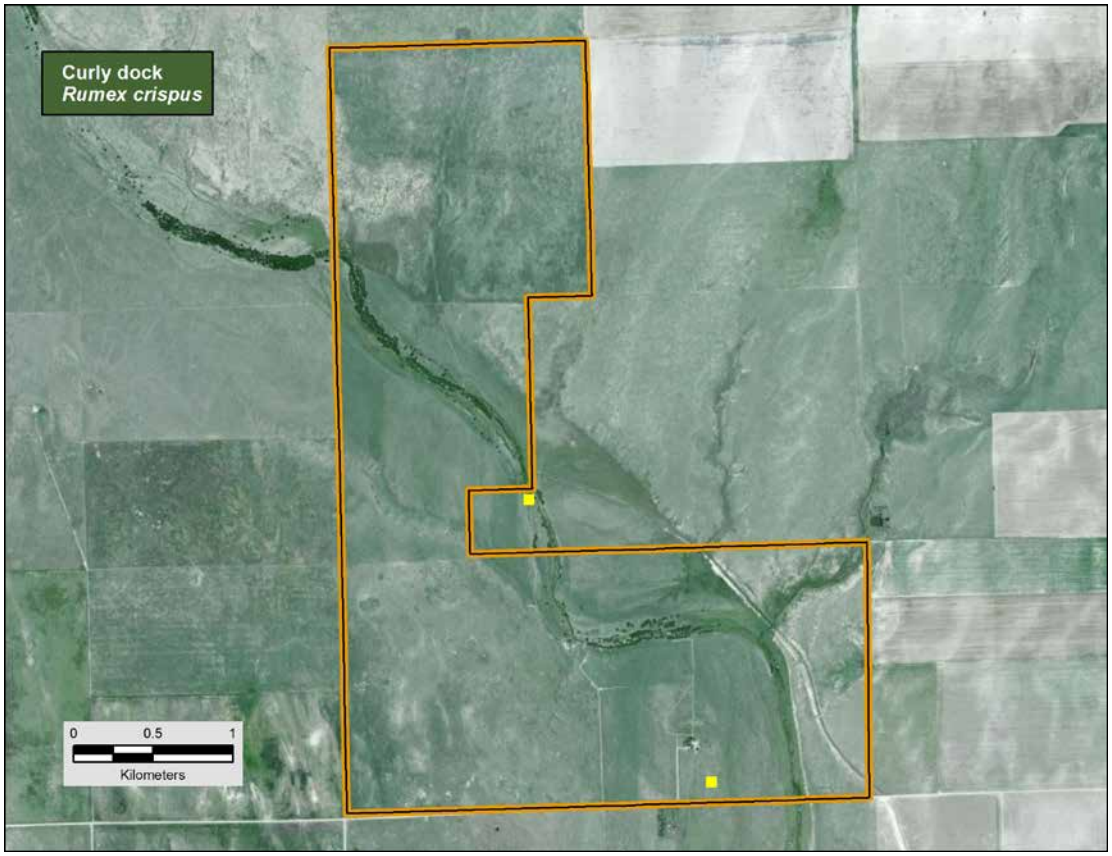


Figure G-10. Curly dock (*Rumex crispus)*

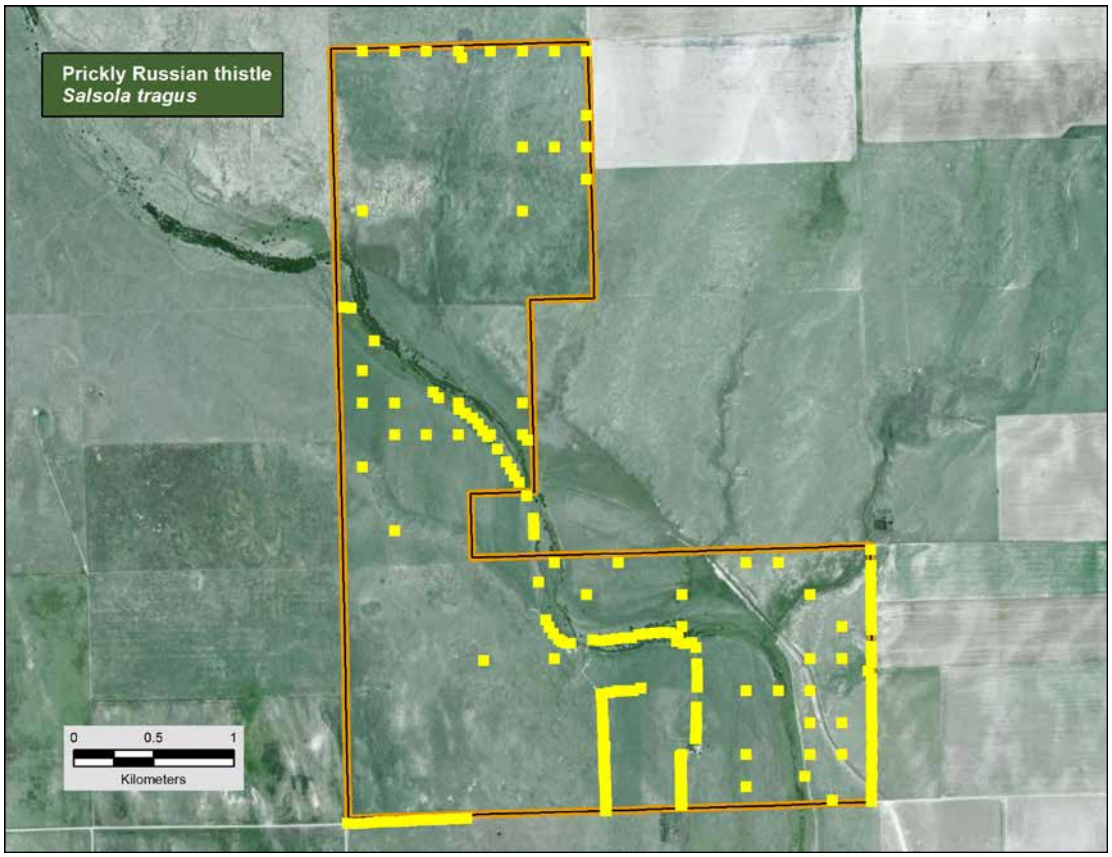


Figure G-11. Prickly Russian thistle (*Salsola tragus)*

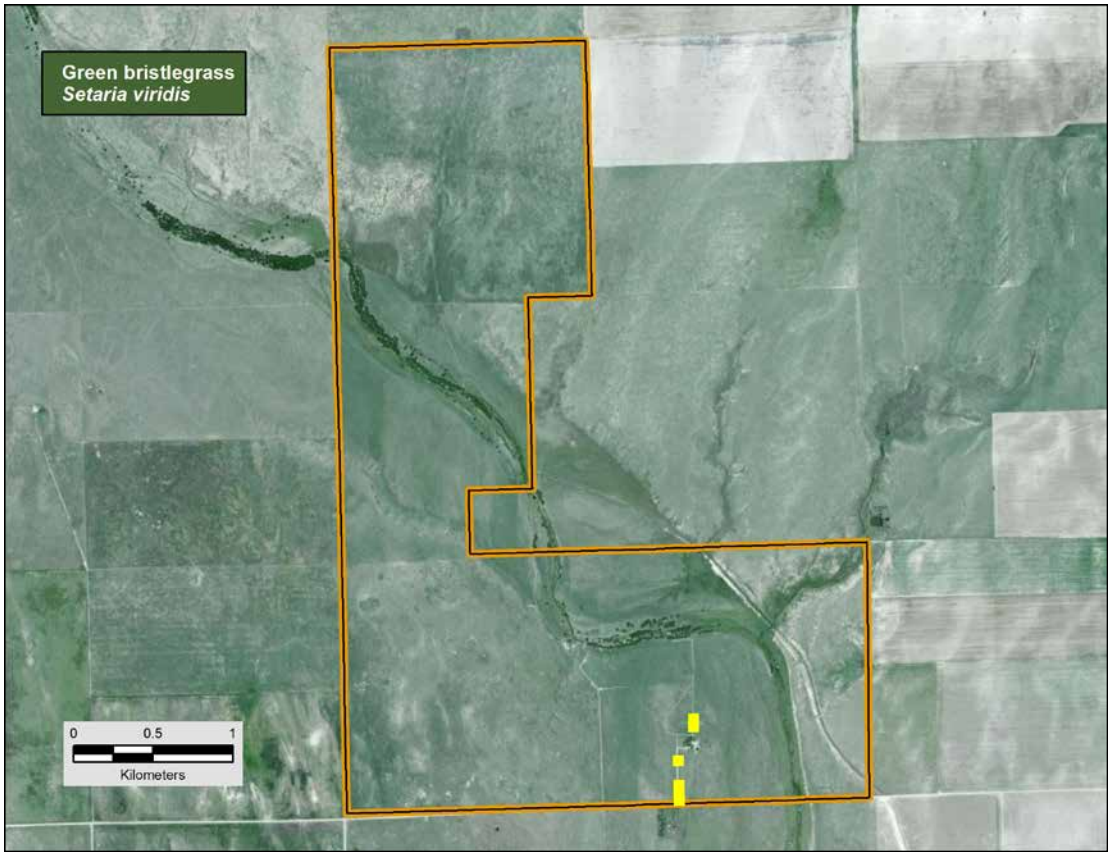


Figure G-12. Green bristlegrass (*Setaria viridis)*

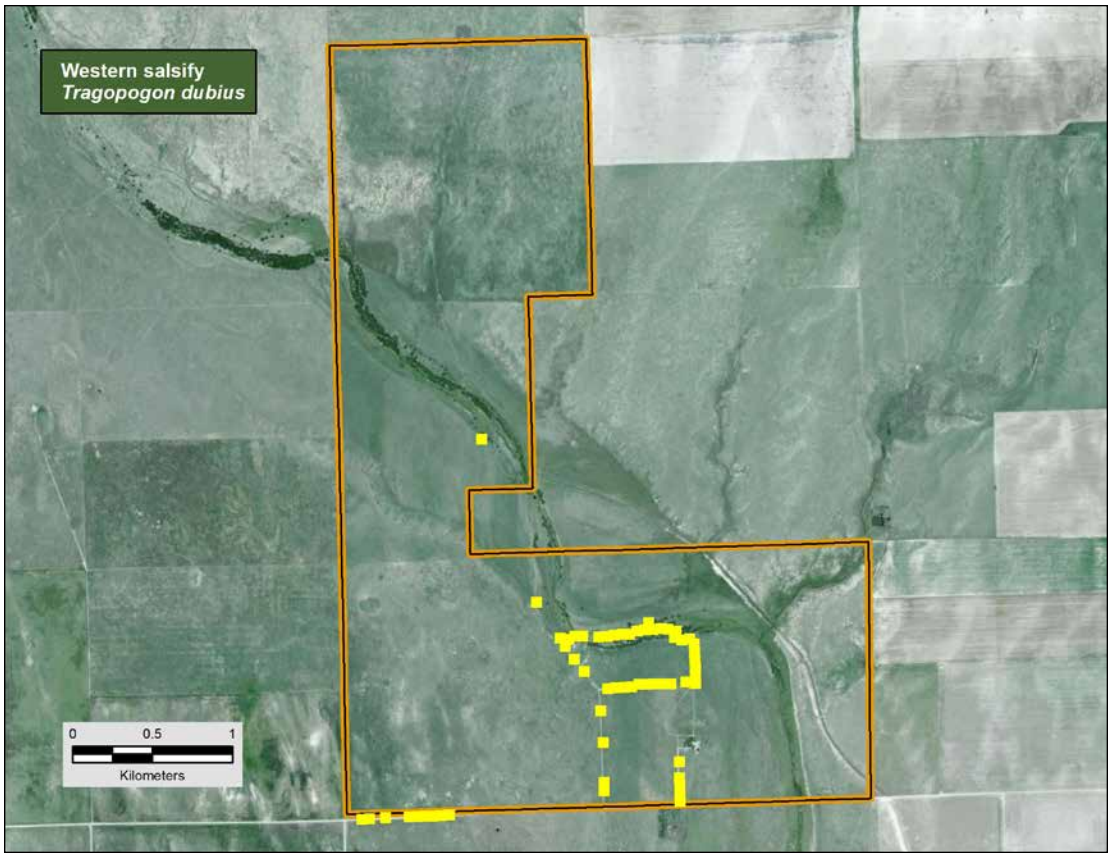


Figure G-13.
Western salsify
(*Tragopogon dubius)*

Appendix H: Background on Bird Species of Conservation Concern Lists

This appendix provides background information on the organizations and efforts to determine species of birds that are in need of conservation. The information preseneted here supports Section 4.11.2, Data and Methods, of the landbirds chapter. This appendix contains some of the same, but additional, information as that section of the report.

One component of the landbird condition assessment was to assess species occurrence in a conservation context. We compared the list of species that occur at Sand Creek Massacre NHS (i.e., those detected during Rocky Mountain Bird Observatory [RMBO] surveys at the NHS during 2009-2012) to lists of species of conservation concern developed by several organizations. There have been a myriad of such organizations that focus on the conservation of bird species. Such organizations may differ, however, in the criteria they use to identify and/or prioritize species of concern based on the mission and goals of their organization. They also range in geographic scale from global organizations such as the International Union for Conservation of Nature (IUCN), who maintains a "Red List of Threatened Species," to local organizations or chapters of larger organizations. This has been, and continues to be, a source of confusion and perhaps frustration for managers that need to make sense of and apply the applicable information. In recognition of this, the U.S. North American Bird Conservation Initiative (NABCI) was started in 1999; it represents a coalition of government agencies, private organizations, and bird initiatives in the United States working to ensure the conservation of North America's native bird populations. Although there remain a number of sources at multiple geographic and administrative scales for information on species of concern, the NABCI has made great progress in developing a common biological framework for conservation planning and design.

One of the developments from the NABCI was the delineation of Bird Conservation Regions (BCRs) (U.S. North American Bird Conservation Initiative 2013). Bird Conservation Regions (BCRs) are ecologically distinct regions in North America with similar bird communities, habitats, and resource management issues. The purpose of delineating these BCRs was to:

- facilitate communication among the bird conservation initiatives;
- systematically and scientifically apportion the U.S. into conservation units;
- facilitate a regional approach to bird conservation;
- promote new, expanded, or restructured partnerships; and
- identify overlapping or conflicting conservation priorities.

Conservation Organizations Listing Species of Conservation Concern

Below we present a snapshot of some of the organizations that list species of conservation concern and briefly discuss the different purposes or goals of each organization.

U.S. Fish & Wildlife Service

The Endangered Species Act, passed in 1973, is intended to protect and recover imperiled species and the ecosystems upon which they depend. It is administered by the U.S. Fish and Wildlife Service (USFWS) and the Commerce Department's National Marine Fisheries Service (NMFS). USFWS has primary responsibility for terrestrial and freshwater organisms, while the responsibilities of NMFS are mainly marine wildlife, such as whales, and anadromous fish.

State of Colorado

Under the authority of the Nongame, Endangered, or Threatened Species Conservation Act, the State of Colorado, through the Division of Wildlife (CDOW) (now Colorado Parks and Wildlife), maintains listings of species considered as threatened or endangered within the State (Colorado Parks and Wildlife 2012). The lists include State special concern species, although this designation is not a statutory category.

USFWS Birds of Conservation Concern

The USFWS has responsibilities for wildlife, including birds, in addition to endangered and threatened species. The Fish and Wildlife Conservation Act, as amended in 1988, further mandates that the USFWS "identify species, subspecies, and populations of all migratory nongame birds (i.e., Birds of Conservation Concern) that, without additional conservation actions, are likely to become candidates for listing under the Endangered Species Act" (USFWS 2008). The agency's 2008 effort, *Birds of Conservation Concern*, is one effort to fulfill the Act's requirements. The report includes both migratory and non-migratory bird species (beyond those federally-listed as threatened or endangered) that USFWS considers the highest conservtion priorities. Three geographic scales are included-- National, USFWS Regional, and the NABCI BCRs. The information used to compile the lists came primarily from the following three bird conservation plans: the Partners in Flight North American Landbird Conservation Plan, the U.S. Shorebird Conservation Plan, and the North American Waterbird Conservation Plan. The scores used to assess the species are based on factors such as population trends, distribution, threats, and abundance.

National Audubon Society/American Bird Conservancy

The National Audubon Society and American Bird Conservancy each formerly published their own lists of bird species of concern, but have recently combined efforts into a single "Watch List". This collaborative effort was based on a concern by these organizations that there were too many lists with similar purposes (Butcher et al. 2007). Their 2007 WatchList is based on, but not identical to, the Partners in Flight (PIF) approach to species assessment (see below).

The 2007 WatchList has two primary levels of concern: a "Red Watchlist" and a "Yellow WatchList", although the latter is subdivided into two categories. The Red WatchList identifies what these organizations consider as species of highest national concern. This list overlaps considerably with the IUCNs "Red List" (not presented here), thus, can essentially be considered as a list of globally threatened birds that occur in the United States (Butcher et al. 2007). The Yellow WatchList is made up of species that are somewhat less critical, but serves as an early warning list of birds that have the potential of being elevated to the Red WatchList. Species on this list can be there either because their populations are declining or because they are considered rare.

Partners in Flight

Partners in Flight is a cooperative effort among federal, state, and local government agencies, as well as private organizations. One of its primary goals, relative to listing species of conservation concern, is to develop a scientifically based process for identifying and finding solutions to risks and threats to landbird populations. Their approach to identifying and assessing species of conservation concern is based on biological criteria to evaluate different components of vulnerability (Panjabi et al. 2005). Each species is evaluated for six components of vulnerability: population size, breeding distribution, non-breeding distribution, threats to breeding, threats to non-breeding, and population trend. The specific process is presented in detail in the species assessment handbook (Panjabi et al. 2005).

Their assessments are conducted at multiple scales. At the broadest scale, the North American Landbird Conservation Plan (Rich et al. 2004) identifies what PIF considers "Continental Watch List Species" and "Continental Stewardship Species." Continental Watch List Species are those that are most vulnerable at the continental scale, due to a combination of small and declining populations, limited distributions, and high threats throughout their ranges (Panjabi et al. 2005). Continental Stewardship Species are defined as those species that have a disproportionately high percentage of their world population within a single Avifaunal Biome during either the breeding season or the non-migratory portion of the non-breeding season.

More recently, PIF has adopted BCRs, the common planning unit under the NABCI, as the geographic scale for updated regional bird conservation assessments. These assessments are available via an online database (http://www.rmbo.org/pif/pifdb.html) maintained by RMBO. At the scale of the individual BCRs, these same principles of concern (sensu Continental Watch List Species) or stewardship (sensu Continental Stewardship Species) are applied at the BCR scale. The intention of this approach is to emphasize conservation of species where it is most relevant, as well as the recognition that some species may be experiencing dramatic

declines locally even if they are not of high concern nationally, etc. There are two categories (concern and stewardship) each for Continental and Regional levels. The details of the criteria for inclusion in each can be found in Panjabi et al. (2005), and a general summary is as follows:

Criteria for Species of Continental Importance

A. Continental Concern (CC)

- Species is listed on the Continental Watch List (Rich et al. 2004)
- Species occurs in significant numbers in the BCR
- Future conditions are not enhanced by human activities.

B. Continental Stewardship (CS)

- Species is listed as Continental Stewardship Species (Rich et al. 2004)
- Relatively high density (compared to highest density regions) and/or a high proportion of the species occurs in the BCR
- Future conditions are not enhanced by human activities.

Criteria for Species of Regional Importance

Regional scores are calculated for each species according to which season(s) they are present in the BCR. The formulae include a mix of global and regional scores pertinent to each season (see Panjabi et al. 2005 for details). The criteria for each category are:

A. Regional Concern (RC)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details)
- High regional threats or moderate regional threat combined with significant population decline
- Occurs regularly in significant numbers in the BCR.

B. Regional Stewardship (RS)

- Regional Combined Score > 13 (see Panjabi et al. 2005 for details)
- High importance of the BCR to the species
- Future conditions are not enhanced by human activities.

Colorado Species of Greatest Conservation Need

In addition to listing threatened and endangered species, the State of Colorado developed a Comprehensive Wildlife Conservation Strategy, also known as a Wildlife Action Plan (CDOW 2006). The plan identifies species and conservation needs for what they consider the Species of Greatest Conservation Need (SGCN). The strategy reflects a basic goal of securing wildlife populations so that they do not require protection through federal or state listing regulations (CDOW 2006).

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Appendix I: Sand Creek Massacre NHS Bird List

Listed below is the full list of species reported to occur or that have occurred at Sand Creek Massacre NHS. In general, the sources did not provide information on residency and abundance classes for each species.

Common Name	2009-2012 Surveys (RMBO)	2005 RMBO Survey/ Inventory (Hanni 2005)	2006 CNHP Rare Species Inventory (Sovell et al. 2008) [1]
American Goldfinch	X		
American Kestrel	X	X	X
American Robin	X	X	X
Baltimore Oriole	X		
Barn Owl		X	
Barn Swallow	X	X	X
Blue Grosbeak	X		
Blue Jay	X	X	X
Blue-winged Teal		X	X
Brewer's Blackbird		X	X
Brown-headed Cowbird	X	X	X
Brown Thrasher	X	X	X
Bullock's Oriole	X	X	X
Burrowing Owl [2]	X [2]	X	X
Cassin's Sparrow	X	X	
Chestnut-sided Warbler		T	
Chipping Sparrow	X	X	X
Clay-colored Sparrow		T	
Cliff Swallow		X	
Common Grackle	X	X	
Common Nighthawk	X	X	X
Common Yellowthroat	X		
Dickcissel	X	X	
Downy Woodpecker	X	X	X
Eastern Bluebird	X	X	X
Eastern Kingbird	X	X	X
Eurasian Collared-Dove	X		
European Starling	X	X	X
Grasshopper Sparrow	X	X	
Great Blue Heron	X	X	X
Great Horned Owl	X	X	X
Hermit Thrush		T	
Horned Lark	X	X	X

1 = The 2006 CNHP inventory was focused on rare species and, therefore, was not a thorough survey for our purposes.

2 = Species observed in 2009 survey (2009 unpublished data collected by RMBO), but not since that time. Absence coincides with prairie dog population collapse.

T = Transient

Common Name	2009-2012 Surveys (RMBO)	2005 RMBO Survey/ Inventory (Hanni 2005)	2006 CNHP Rare Species Inventory (Sovell et al. 2008) [1]
House Finch	X		
House Wren	X	X	X
Indigo Bunting		T	
Killdeer	X	X	X
Lark Bunting	X	X	X
Lark Sparrow	X	X	X
Lincoln's Sparrow		T	
Loggerhead Shrike		X	X
Mallard	X	X	X
Mountain Plover [2]	X [2]	X	X
Mourning Dove	X	X	X
Northern Flicker	X	X	X
Northern Harrier		X	X
Northern Mockingbird	X	X	X
Orchard Oriole	X	X	X
Red-headed Woodpecker	X	X	X
Red-tailed Hawk	X	X	X
Red-winged Blackbird	X	X	X
Ring-necked Pheasant	X	X	X
Rock Pigeon (Rock Dove in Sovell et al. 2008)			X
Rock Wren		X	
Say's Phoebe	X	X	X
Scaled Quail		X	X
Short-eared Owl		X	
Spotted Towhee		X	X
Swainson's Hawk	X	X	X
Swainson's Thrush		T	
Turkey Vulture	X		X
Vesper Sparrow		X	X
Warbling Vireo	X		
Western Kingbird	X	X	X
Western Meadowlark	X	X	X
Western Wood-Pewee	X	X	
White-crowned Sparrow		X	X
White-faced Ibis			X
Yellow Warbler	X	X	X
Yellow-billed Cuckoo	X		
Yellow-headed Blackbird			X
Yellow-rumped Warbler			X

1 = The 2006 CNHP inventory was focused on rare species and, therefore, was not a thorough survey for our purposes.

2 = Species observed in 2009 survey (2009 unpublished data collected by RMBO), but not since that time. Absence coincides with prairie dog population collapse.

T = Transient

Appendix J: Bird Distribution List

The distribution status of species reported to occur or have occurred at Sand Creek Massacre NHS was determined using Birds of North America species accounts as a general reference. Comparisons with reference conditions were made only for species for which the NHS was within, or less than 100 miles from, their normal breeding range.

Common Name	Breeding Status
American Goldfinch	Year-round
American Kestrel	Breeding and Wintering
American Robin	Breeding and Wintering
Baltimore Oriole	Outside Normal Breeding Range [1]
Barn Owl	Breeding and Wintering
Barn Swallow	Breeding
Blue Grosbeak	Breeding
Blue Jay	Year-round
Blue-winged Teal	Breeding
Brewer's Blackbird	Outside Normal Breeding Range [1]
Brown-headed Cowbird	Breeding
Brown Thrasher	Breeding
Bullock's Oriole	Breeding
Burrowing Owl	Breeding
Cassin's Sparrow	Breeding
Chestnut-sided Warbler	Outside Normal Breeding Range
Chipping Sparrow	Outside Normal Breeding Range
Clay-colored Sparrow	Outside Normal Breeding Range
Cliff Swallow	Breeding
Common Grackle	Breeding
Common Nighthawk	Breeding
Common Yellowthroat	Breeding
Dickcissel	Peripheral Breeding Range
Downy Woodpecker	Year-round
Eastern Bluebird	Outside Normal Breeding Range [1]
Eastern Kingbird	Breeding
Eurasian Collared-Dove	Year-round
European Starling	Year-round
Grasshopper Sparrow	Breeding
Great Blue Heron	Year-round
Great Horned Owl	Year-round
Hermit Thrush	Outside Normal Breeding Range [1]
Horned Lark	Year-round
House Finch	Year-round
House Wren	Breeding
Indigo Bunting	Outside Normal Breeding Range [1]
Killdeer	Breeding

[1] Species is outside of its normal breeding range, but less than 100 miles from the edge of its breeding range.

[2] Species is >100 mi from its breeding range edge based on BNA, but recent evidence suggests it is < 100 mi from its breeding range edge (R. Lock., RMBO, pers. comm.).

Common Name	Breeding Status
Lark Bunting	Breeding
Lark Sparrow	Breeding
Lincoln's Sparrow	Outside Normal Breeding Range
Loggerhead Shrike	Breeding
Mallard	Breeding and Wintering
Mountain Plover	Breeding
Mourning Dove	Year-round
Northern Flicker	Year-round
Northern Harrier	Year-round
Northern Mockingbird	Year-round
Orchard Oriole	Outside Normal Breeding Range [1]
Red-headed Woodpecker	Breeding
Red-tailed Hawk	Year-round
Red-winged Blackbird	Year-round
Ring-necked Pheasant	Outside Normal Breeding Range [1]
Rock Pigeon	Year-round
Rock Wren	Breeding
Say's Phoebe	Breeding
Scaled Quail	Outside Normal Breeding Range [1]
Short-eared Owl	Outside Normal Breeding Range [2]
Spotted Towhee	Outside Normal Breeding Range [1]
Swainson's Hawk	Breeding
Swainson's Thrush	Outside Normal Breeding Range
Turkey Vulture	Outside Normal Breeding Range
Vesper Sparrow	Outside Normal Breeding Range [1]
Warbling Vireo	Outside Normal Breeding Range [1]
Western Kingbird	Breeding
Western Meadowlark	Year-round
Western Wood-Pewee	Breeding
White-crowned Sparrow	Wintering
White-faced Ibis	Outside Normal Breeding Range [1]
Yellow Warbler	Breeding
Yellow-billed Cuckoo	Outside Normal Breeding Range[1]
Yellow-headed Blackbird	Breeding
Yellow-rumped Warbler	Outside Normal Breeding Range

[1] Species is outside of its normal breeding range, but less than 100 miles from the edge of its breeding range.

[2] Species is >100 mi from its breeding range edge based on BNA, but recent evidence suggests it is < 100 mi from its breeding range edge (R. Lock., RMBO, pers. comm.).

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